Biological
& Medical
Serials

Public health bulletin
no.103-104

TREASURY DEPARTMENT
UNITED STATES PUBLIC HEALTH SERVICE

PUBLIC HEALTH BULLETIN No. 103
JUNE, 1919

THE RAT

ARGUMENTS FOR ITS ELIMINATION AND METHODS FOR ITS DESTRUCTION

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THE RAT.[1]

It is a widespread and very popular belief that, however obnoxious an animal parasite may be, it has some compensatory feature attached to its existence; that in nature's scheme of affairs it fulfills some useful purpose.

A thoughtful consideration of the rat, however, fails to reveal any redeeming feature that could justify a tolerance of this highly destructive and disease-bearing pest. Perhaps in other ages and under different sanitary conditions than now exist in civilized communities the rat served as a much needed scavenger; but changing conditions have robbed the rat of even this questionable argument for existence.

The economic losses occasioned by this animal and the menace its presence causes through its disease-bearing potentialities have aroused people to make widespread warfare against rats, but such efforts have been to a great degree spasmodic and individual, rather than collective.

Any estimate of the rodent population of the United States can be nothing less than a conjecture, but a guess of one rat per person would probably be conservative. Such an estimate would be supported by the intensive studies of the United States Public Health Service in its sanitary campaigns in several large cities, in which the rodent population was calculated on trapping percentages.

Guesswork likewise enters into any computation of economic losses due to damages done by the rat, since many of them subsist throughout their lives on garbage or other refuse; but, on the other hand, the losses incurred by one rodent's depredation in a single night has amounted to many dollars.

SPECIES AND PREVALENCE IN THE UNITED STATES.

In general, there are three varieties of rats in American cities, excluding mice: the brown rat, variously known as the "Norway" rat, barn rat, sewer rat, gray or wharf rat, is the most common species. There is, however, a considerable number of black rats, and roof or "Alexandrian" rats. Owing to the antagonism of the larger and more ferocious brown rat, these two latter species are but rarely found in the United States, except in seaports.

[1] This article was prepared by direction of the Surgeon General and was originally published by the Women's Municipal League of Boston.

None of these species is native to the United States. They were all imported. The brown rat is said to have come into Europe from northern Asia, arriving in England early in the eighteenth century, and shortly thereafter, or about the beginning of the American Revolution, its presence was noted in this country. Strange to say, the black rat, which is now regarded as a visitor in our seaports, preceded the brown rat by several centuries both in Europe and in America. It was introduced into England in the twelfth century, and reached America four centuries later. The black rat is said to have come from southern Asia, and the Alexandrian, or roof rat, to have originated in Egypt. The arrival of the more powerful brown rat was generally followed by the disappearance of the smaller ones. Either they were destroyed or migrated. It thus happens that while the black rat was the first arrival, it is now but seldom seen, and this is just as well since the habits of the black rat make it more dangerous to the human population, so far as disease-transmission is concerned, as it lives more within buildings than does the Norway rat, and thus comes in closer contact with man.

The black rat is about two-thirds the size of the brown rat, has a bluish-black fur, smaller head, large rounded ears, and a tail that is longer than the body. The tail and ear of the black rat are two of the main distinguishing features, since the tail of the brown rat is somewhat shorter than its body, and the ears are pointed and comparatively smaller than those of the black rat. The size and shape of the roof rat is similar to the black rat. Its fur, however, is a light gray on back and sides, with white belly.

HABITS.

Some knowledge of the rat's habits is essential to intelligent effort toward its destruction. Rats are notoriously prolific. The female rat produces from three to five litters yearly, and has been known to bear young monthly throughout the year. The average litter of the brown rat is eight and that of the black rat is five. As might be supposed, the death rate is high amongst the newly born, and generally the half-grown litter numbers about four. The preservation of species is not wholly due to fecundity, for the animal in its fight for existence has to develop remarkable cunning and resourcefulness in adapting itself to cohabitation with man.

The Norway rat is essentially a burrowing animal, and by preference lives and breeds in excavations. In the majority of instances the burrows extend from one-half to 1 foot. It will burrow in the ground when it already has sufficient covert beneath flooring space. While the depth to which a rat will burrow under natural conditions has generally been observed to be not greater than 1½ feet, excavations have been noticed passing beneath walls 2 feet deep. This, however,

is rare. The brown rat apparently burrows with greatest ease, even in the hardest grounds, such as well-packed clay. The same species will pass through walls made of brick or irregular stone, provided the mortar is not composed of cement. Observations have been made of places where a Norway rat has perforated walls in which the construction was of sun-dried brick, held together by sand and lime mortar. In some instances the rat run actually pierced the body of the brick, a smooth-beveled hole having been produced. More frequently, though, the wide interstices, filled by sand and lime mortar, were the points perforated. Whether this operation was performed by burrowing or by gnawing can not be stated, but it was probably accomplished by gnawing. The English Plague Commission has accredited the Norway rat with the ability to gnaw through brick or concrete, but it is incredible that rats can successfully attack properly made concrete. Instances have been noted where a rat has been able to gnaw a hole in slate, and lead pipe is not infrequently perforated by its attack. This is not so surprising when we consider the facility with which its fellow rodent, the squirrel, can dispose of hard shell, such as walnut or hickory nut.

In swampy regions the brown rat has adapted itself to semiaquatic habits, and when put to the test has been known to swim one-half mile in an open bay. The Norway rat has not the ability of the smaller species, but when necessary can climb ropes, wires, or trees and make a broad jump of 2 feet or more. It is very pugnacious and to some extent cannibalistic.

The black rat and the roof rat have the same habits, although the former seems to prefer urban and the latter rural environment. The Alexandrian rat is the common cane field rat of the West Indies and the tree rat of the tropics, but it is frequently found about buildings in common with the black rat. The black rat ordinarily does not burrow, but lives in hollow walls, garrets, or loose material, such as empty boxes, barrels, or any rubbish, and within buildings frequents the upper stories and the roof, away from its enemy, the brown rat, and climbs pipes, wires, and the exposed uprights with the greatest facility. The black crescents made by these rats on exposed joists are very striking. The markings can be observed on the face of the joists, immediately beneath the floor beams, and comes from the grease and dirt of the rat's fur as he swings under the floor beams, where they intersect the joists. Its agility is remarkable, and it has been observed, when attempting to escape, to run up a bare brick wall to a height of 6 feet. An empty iron can of 2 feet depth is not sufficient to retain the black rat.

The Norway rat is not at all choice in its preference for food. It will eat anything. The black rat, however, is more select in its taste and prefers grain or clean food. It is a poor scavenger.

Rats are nocturnal in their habits and can see better at night. When traveling in the daytime the rat seems uncertain of its movements, unless running along a wall, where its vibrissæ or "feelers" apparently are of service in guiding it. The black rat is even warier than the brown rat and consequently is more difficult to trap. It is rather exceptional to catch a black rat in a cage trap, snap traps or dead falls being more reliable for capturing this species.

The rat is a great traveler, both overland and by transportation. From a number that were released in a large city, one was recaptured after two days at a point 1 mile distant from the place of liberation, and several were retaken, in the course of two weeks, 2 and 3 miles from the point of release. Their travel had been through a thickly populated area of the city and across many city streets, some of them wide thoroughfares. They are not infrequently found in freight cars, and practically nearly every ship that enters a port brings a large number of rats, unless artificial means have been carried out for destroying these undesirable stowaways. The number of rats taken from ships by fumigation and trapping has on frequent occasions amounted to several hundred.

DESTRUCTIVENESS.

Intensive, thorough studies of damage done by rats are lacking, but sufficient random observations are available to make it certain that the cost of maintaining rats is a big economic drain on the Nation. To assign any accurately fixed sum to the amount of injury done by rats in the United States is impossible, but estimating the loss at a rational minimum amount the sum is astounding. The calculation embraces two factors, i. e., the rodent census and the average amount of damage done by one rat. Both of these factors can be determined within reasonable limitations. By means of trapping percentages covering a period of 1 year, it has been determined that the rodent population in several American cities is slightly in excess of the human population. In the rural districts of the United States the number of rats on any farm or plantation will easily average three or four times the number of people on the estate, and in the grain or cane producing areas the proportion will be multifold.

It has been determined that the rat will consume 50 pounds of grain in a year and will damage considerably more. The estimate of one rat per human being for the continental United States coincides with that for Great Britain and Ireland, made by the Incorporated Society for the Destruction of Vermin, and also for authoritative figures for Denmark, France, and Germany. The annual upkeep per rodent was computed by the same authorities as $1.80 in Great Britain, $1.20 in Denmark, and $1 in France. The depredations of rats in this

country will probably exceed the estimate made for Great Britain. One-half cent per day would be a conservative estimate, however.

The list of articles damaged by rats is too long to enumerate in detail, but in general they are all kinds of grain, before and after harvesting; eggs and poultry, especially small chicks; wild birds, their eggs and young; fruits and vegetables, both when growing and when stored; flowers, bulbs, and shrubbery, all kinds of staples in bags or boxes; and all food products in pantries, groceries, meat markets, bakeries, stables, and general markets. The nonedible articles destroyed include leather goods, books, papers, clothing, and fabrics, partly for the glue, starch, or paste these articles may contain, and also for material for the rat's nest.

Lantz, in Public Health Bulletin No. 30, entitled "The Rat and Its Relation to Public Health," cites the following specific cases of rat depredations:

> An Iowa farmer, writing to an agricultural journal, reported that rats had destroyed in one winter about 500 bushels of corn, stored in cribs, or one-fourth of his entire crop. Another farmer reported that rats had robbed him of an entire summer's hatching of 300 or 400 chicks; and still another attributed his loss in grain and poultry for one season, due to rats, as sufficient to pay his taxes for three years.

Lantz further quotes a Washington merchant to the effect that rats gnawed a hole in a tub containing 100 dozen eggs, and within a period of two weeks carried away 71 dozen, without leaving either shell or stain. The writer once observed in San Francisco a shop dedicated to the sale of manicure supplies that was so rat-infested that the proprietor had to move on account of the damage done to the articles made from leather or chamois skin. The reports of experimental stations in Guam, Hawaii, and Porto Rico lay special stress on the depredations of rats in the cane fields. The annual loss to cane growers in Porto Rico is estimated at $75,000, due not only to the cane actually destroyed, but also to the fermentation set up in the cane juices in the stalks that had been gnawed upon, thus reducing the purity and the sucrose content. This loss was based upon the estimate that only one-half of 1 per cent of stalks were attacked by rats; but in reply to inquiries, the estimates made by different planters varied from 1 per cent to 4 per cent of stalks attacked by rodents.

Because the rat is an animal of nocturnal habits, its depredations often pass unnoticed or are ascribed to other causes.

Computing the upkeep of the rat as one-half cent per day, and estimating one rat to each person, the sum of $180,000,000 per year is lost to the country by the depredations of this pest. It is on shipboard that rats commit the greatest damage. A ship recently entered a southern port with a cargo of coffee from Brazil. Upon dis-

charging cargo it was found that 30,000 bags out of the total of 40,000 had been so damaged that resacking was necessary. The cost of this procedure in value of material and expense of labor was estimated at $2,000, and this sum did not include the loss of coffee or damage adjustment with the shippers, yet the total number of rats on the ship was only some 200.

RATS AS DISEASE TRANSMITTERS.

Rats have been the agents in transmitting bubonic plague into all parts of the world. According to authoritative records, this disease has, in recent centuries, destroyed millions of lives. To-day plague exists in the rats of several English seaports, in Southern Europe, Africa, and in practically all the ports of the Orient. It is also present on the east and west coasts of South America. Plague has not only caused an enormous loss of lives, but the measures for its control have cost many million dollars.

Rats are frequently infected with intestinal parasites, especially tapeworm. Trichina is also found in rats, and these rodents are probably a considerable factor in transmitting the infection among hogs, from whence it may infect men.

Of all disease-bearing parasites the rat stands supreme in the cost its presence has entailed upon mankind in toll of lives and money.

METHODS OF DESTRUCTION AND PREVENTION.

Rat destruction can be accomplished by individual effort to a limited degree, but to be successful in a large city the measures attempted must be communal in nature—i. e., the rat proofing of buildings. No spasmodic or individual effort will result in the desired end.

Rats can be destroyed by trapping, by poisoning, and by using natural enemies, such as certain breeds of cats and dogs. To insure the success of these measures it is necessary to curtail the rat's food supply by properly disposing of garbage and table refuse, and by preventing rats from gaining access to such food as is contained in pantries, groceries, markets, stables, etc. The municipal government will have to assist the efforts of the citizens along this line by creating and enforcing rat-proofing laws. To merely keep premises clean and free of rubbish will be of but little benefit, as Norway rats, even when abundant rubbish is available, prefer more secure covert, as that beneath floors, and within double walls and ceilings.

Much has been written about rat trapping, the pattern of trap or kind of bait, and methods of trapping; but after all has been said and done, it still remains probable that success in trapping is proportional to the attention and industry the trapper devotes to his traps and the

protection of other food supplies. Two kinds of traps are generally used—the wire cage trap and the snap trap or dead fall. To obtain the best results the traps must be well attended and frequently moved from one place to another. Large cage traps, 20 inches in length, are much more effective than the smaller ones. The placing of traps is important. They should be placed wherever rats have been accustomed to come for feeding purposes and should be more or less concealed, the small snap traps by scattering dust, flour, or corn meal on or about them, and the cage trap by pieces of sacking, straw, or rubbish, leaving only the opening free.

The prerequisite of successful trapping is that no food, other than the bait, shall be available to the foraging rodents. Other things being equal, highly savored articles, such as cheese and toasted bacon, will more quickly attract rats than will food without odor; but the idea that a rat can be enticed into a trap by the employment of bait more appetizing to him than the surrounding food supply is fallacious. To the rat, food supply is a question of availability, and preference is of secondary consideration.

Generally speaking, however, it is probable that the rodent which frequents a grain house is most successfully trapped by the use of grain; and in meat markets, meat may be the best bait; or, again, rats found in green groceries, where vegetables are kept, are more easily attracted by baiting the trap with vegetables.

The destruction of rats by poison has always been more or less in favor. A preparation of arsenious acid or phosphorus, 10 per cent in suitable base, as cheese, meal, or glucose, are the most popular poisons in use. Strychnine placed inside pieces of food, or grain impregnated by its solution, is used to some extent, as is also plaster of Paris in the proportion of 1 part to 2 parts of flour. This forms enteroliths and eventually kills the rodent. Poisons undoubtedly have a certain efficiency in ridding a place of rats, but whether by causing their migration or their actual destruction is somewhat difficult of determination. At best it is haphazard and uncertain. The effectiveness is always a matter of conjecture, and there is doubt as to whether the results compensate for the labor expended.

There is nothing in doubt as to the results of trapping. The employment of the natural enemies of the rat, such as dogs, cats, mongoose, or weasels, is at best only a feeble auxiliary measure. The writer has frequently seen places overrun with rats, notwithstanding the presence of the above-mentioned natural enemies. Undoubtedly some breeds of cats and dogs are better than others for rat-catching purposes, but the average domestic cat or dog is not a success in preventing rodent infestation, owing to the protection of artificial harborage afforded to the rat.

Rat proofing excludes rats from the food supply, and deprives them of a harborage. Without this procedure it is almost impossible to materially reduce the rodent population.

The Japanese authorities have depreciated the value of trapping and poisoning as an antirat measure, contending that with the temporary reduction in rat population by these measures, the relatively increased food supply and harborage stimulated breeding and longevity of rat life to a compensatory degree. In this argument several eminent Indian authorities on plague agree, notable among whom was Maj. Morehead, who said, "rat destruction is of doubtful value." Obviously it is true that partial rat destruction alone will provide more favorable conditions for propagation to the remaining population, but, if the harborage is destroyed and foodstuffs protected, the favorable conditions for breeding are eliminated. Without the general enforcement of rat proofing, antirat measures are bound to be more or less temporary and decidedly unsatisfactory.

In rat proofing any building the following parts have to be considered: Ground area, walls, ceiling, garret, roof, dead spaces in general, ventilators, abandoned sewers, doors, windows, outside piping, water and sewage pipes, downspouts, wiring, and air or light shafts. By the omission of some small detail an otherwise rat-proof structure may become badly rat infested.

The rat proofing of floors of buildings is secured either by elevation of the structure with the underpinning open and free or by marginal walls of concrete, stone, or brick laid in cement mortar sunk 2 feet into the ground, fitting flush with the floor above. The wall must fit tightly to the flooring and not merely extend to the joists or supporting timbers, as this would result in open spaces for the entrance of rodents.

Food depots are of the greater importance in rat proofing because they furnish both sustenance and shelter for rats. In this class of buildings are stables, meat markets, retail and wholesale groceries, bakeries, warehouses, docks, and wharves. These places are best rat proofed as to the ground areas by the construction of concrete floors and foundation walls. Untenanted as they are at night time, rats might well enter doorways or windows carelessly left open, or be introduced concealed in the merchandise, and, gnawing through plank flooring, obtain well-protected hiding and breeding places.

To render a large livery stable entirely rat proof is hardly practicable, owing to the doors being open almost continuously, but rat proofing even in such buildings will destroy rat harborage and limit rat invasion to an occasional migratory rodent. With concrete floor-

ing, foundation walls, and protected feed bins it is a comparatively easy task to maintain the building relatively rat free.

Structures that are difficult to keep rat free, even though structurally rat proof, are storage wharves and large wholesale warehouses where immense quantities of provisions remain stored during long periods.

Rat proofing by elevation is chiefly applicable to small and medium size buildings. The intent is to have sufficient elevation, about 2 feet, so that the ground area beneath shall be as exposed and free from covert as unbuilt-upon land.

For more pretentious dwellings, where sufficient care can be exercised to prevent rodents from gnawing through plank flooring, a marginal rat proof foundation wall will suffice.

Double walls with a dead space between should be avoided or if used should be rat proofed at top and bottom with heavy wooden timbers, 4 by 4 joists, or by a concrete fill. Attics should be well opened and kept free of dunnage or other refuse for rats.

Double ceiling should be avoided, especially so in basements. Boxed-in structures, such as uprights in roughly finished dwellings, plumbing, kitchen sinks, and sundry similar arrangements, often furnish rat harborage. Such boxing should be removed. Porches and steps should be given the same consideration as the body of the house.

Miscellaneous openings, as light shafts, ventilators, and open windows, should be screened, preferably by 12-gauge wire screen with mesh not exceeding one-half inch. Abandoned sewers or drainpipes at times give access to rodents and should be protected.

The garbage depository must be given careful attention. It should be of metal, preferably a galvanized-iron can, water-tight to prevent seepage which would attract rats, and should have a closely fitting lid. A can 2 feet in height without cover will not be proof against the incursion of rats.

The grounds around a building are to be devoid of rat harborage. Premises are to be kept clean and free of rubbish. Plank walks and plank covering for yards are to be avoided. Cinders or concrete are preferable for this purpose. If the latter material is used it should have marginal protection to prevent rodents from burrowing beneath.

Chickens, goats, hares, pigs, and other animals that are generally fed on table scraps ought not to be allowed within the city limits.

Chicken yards when so permitted may be rat proofed by a concrete wall at the periphery, sunk into the ground 2 feet or more, with one-half inch mesh wire netting covering the top and sides.

The top netting is necessary, as otherwise rats can easily climb the sides and enter the pen. The writer has personally observed the Norway rat (which is not a climber like the black rat) scale a piece of wire netting 3 feet high. The feat was so rapidly performed that a laborer purposely stationed at the spot was not quick enough in action to strike the escaping rodent.

Loose materials about the yard should be piled on platforms 2 feet high.

A rat-proofing law should provide a minimum standard for concrete, both as to quality and quantity of its component parts and the dimensions of the construction. The thickness of the floors should be not less than 3 inches of concrete with a half-inch capping of cement, and of walls not less than 6 inches. Standard brands of cement, clean sharp sand, and hard stone in proportion 1:2:3, or as approved by a competent engineer, ought to be required in all concrete construction.

ROUT THE RAT!

By starving him, through the use of rat-proof receptacles for food, and covered metal garbage cans.

By depriving him of breeding places, through the abolition of planked yards and passageways.

By refusing him admission to the comfort of your buildings, through rat-proof construction, and screened basement openings.

By killing him at every opportunity.

By demanding city antirat ordinances and State antirat laws.

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Sanitary Engineers and Other Officers of the Public Health Service Directing Antimalaria Campaign

Held at Wilmington, N. C.
February 17–20, 1919

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First Annual Conference of Sanitary Engineers and Other Officers of the Public Health Service Directing Antimalaria Campaign.

TRANSACTIONS.

The first annual conference of sanitary engineers and other officers of the Public Health Service engaged in directing antimalaria campaigns was held in Wilmington, N. C., February 17–20, 1919.

The following persons were present at the conference:

Asst. Surg. Gen. H. R. Carter.

Prof. C. W. Stiles.

Senior Sanitary Engineer J. A. A. Le Prince.

Asst. Surg. L. L. Williams.

Sanitary Engineers C. M. Baker, H. R. Crohurst, L. M. Fisher, L. C. Frank, C. N. Harrub, J. K. Hoskins, W. H. W. Komp, W. E. Stromquist, R. E. Tarbett, H. H. Wagenhals, and H. W. Van Hovenberg.

Assistant Sanitary Engineers J. F. Base, G. H. Bishop, J. L. Clarke, J. G. Foster, A. W. Fuchs, H. R. Fullerton, A. E. Gorman, W. A. Hardenburg, W. E. Hardenburg, L. D. Mars, F. D. Messenger, E. H. Paddock, H. E. Phelps, Sol Pincus, William Roper, F. R. Shaw, A. J. Smalshof, C. H. Spaulding, H. F. S. Tait, W. D. Tiedeman, and A. J. Willison.

Biologist M. B. Mitzmain.

Scientific Assistants A. F. Allen, W. Bryce-Delaney, H. W. Snidow, and H. C. Woodfall.

Epidemiologist T. H. D. Griffitts.

Special Investigator C. W. Metz.

Inspectors W. A. Davis, L. G. Hastings, and R. B. Sullivan.

Visitors Dr. Mitchell Carroll, William Delaney, and Capt. R. W. Geis, of New Jersey; Lulu Frere, Max Kisliuk, jr., and Gethyn Reagan, of the Marine Hospital, Wilmington, N. C., and G. S. Holway, State Board of Health, Richmond, Va.

FEBRUARY 17, 1919.

Through the courtesy of the Chamber of Commerce of Wilmington automobiles had been provided to take all who were attending the conference on a tour of inspection of the malaria-control operations in the vicinity of Wilmington. The party assembled at the Wilmington Hotel at 9 a. m. The tour included inspection of abandoned rice fields in which no work had been done; abandoned rice fields in which control measures had been carried out; various types of tide gates; and pond and stream control, and ended at the hotel at 1.30 p. m. As the various features observed were later described and discussed at the conference they will not be considered in detail at this time.

The first meeting was called to order in the chamber of commerce at 2 p. m. February 17, by Asst. Surg. Gen. H. R. Carter.

THE MALARIA PROBLEM OF THE SOUTH.

OPENING REMARKS OF ASST. SURG. GEN. H. R. CARTER.

As you know the hot countries are preeminently the home of protozoal infections and in the diseases of the South of the United States one such disease stands preeminent for the injury it does. It is malaria. In that section none of the bacterial diseases is in its class for the injury it does—no; I do not except tuberculosis.

Just one word on the importance of this disease—I mean its importance as compared with the other diseases of which the sanitarian takes account. And here let me say that in this I am only considering such parts of the South (and Southwest) in which malaria prevails so as to be a serious sanitary problem. In many sections of the South it is no problem at all; in many others a very minor problem, but in those sections in which it is really prevalent it is easily the most important sanitary problem we have. It stands first on the list for the injury it does the community.

The public generally has no conception of the seriousness of malaria as a health problem in the United States. Yet it is well established that wherever malaria prevails the population is generally subnormal physically, mentally, and economically. Since competent authorities estimate the number of cases of malaria occurring annually in the United States at the present time at about six or seven million, the influence of this disease on the health and welfare of the Nation demands wider recognition. It is especially important to overcome the apathy with which malaria is still so frequently regarded, mainly because it is so seldom fatal. The occurrence of small pox, typhus fever, cholera, or yellow fever rouses to instant activity the press, the people, and the health authorities. Yet the ravages of these diseases in this country are as nothing when compared to the devastation wrought by malaria.

This is perhaps not unnatural, for in the case of the first-mentioned diseases, the events are usually much more dramatic. These diseases run a short course and a large proportion of the cases quickly end with death. In the case of malaria, the disease runs an insidious, chronic course, and there are few fatalities. Under these circumstances, the havoc wrought by malaria is not readily appreciated.

When one considers the rôle played by health conditions in rural communities in influencing those prevailing in towns and cities, and

furthermore the relation existing between the health of one part of the United States and that of the Nation as a whole, it becomes clear that the problem of malaria control throughout the United States is one which would be dealt with through the cooperation of Federal, State, and local authorities.

One of our southern health officers says, "We must direct our work against that group of diseases which gives the heaviest mortality, because the reduction of mortality is, in the last analysis, the measure of our success." I count him wrong in his criterion of success, doubly wrong if he understood "mortality" to be the same as "recorded mortality." The recorded mortality of a disease frequently does not indicate its true influence on the death rate. This is eminently true of malaria. From its effects, direct and economic, in lowering the general vitality of a community, it is a casual factor in many a death in which it is not the terminal factor, the one recorded as the "cause of death." Mortuary statistics do not, then, give the proper weight of this disease as a cause of death.

It is not in its death rate, however, that the gravest injury of malaria lies. It is in its sick rate; in the loss of efficiency it causes rather than in the loss of life. One death from pneumonia should correspond to about 125 sick days, days not working; 1 of typhoid fever, 450 to 500; 1 of tuberculosis to somewhat more among whites, decidedly less among negroes. A death from malaria, however, corresponds to from 2,000 to 4,000 sick days. This loss of efficiency may really be doubled or trebled, as the man infected with malaria is frequently half sick all the time.

And it is the extent of malaria when it is bad, the number of people attacked, as compared with other diseases which appals. If there is 1 per cent of typhoid, it is an epidemic and a bad one; 40 to 60 per cent of a population per annum is not uncommon for malaria, and I have seen outbreaks with 90 per cent. The injury to efficiency caused by malaria in the country of the malarious section of the South is beyond comparison greater than that caused by any other disease—any two or three diseases, including typhoid and tuberculosis combined.

I am not speaking at random. You do not know of an instance where the prevalence of typhoid fever determined the location of industrial plants. Malaria is a determining factor. At one place where power from a hydroelectric plant was abundant and very cheap the manager told me that a number of options for cotton mills, wagon factories, etc., had been taken up on account of the cheapness of the power, but had been abandoned on account of the prevalence of malaria.

Has the presence of tuberculosis ever prevented a real estate transaction? I know of a deal involving the purchase of a large tract of

land—about a half million dollars' worth—for colonization not consummated on account of the existence of malaria in that section, and there was not much either. You have not seen homes abandoned on account of either tuberculosis or typhoid. I have seen them abandoned on account of malaria.

At one time malaria was at home in a much greater area of the United States than it is to-day. Even in the South, where malaria is still prevalent, the disease is diminishing in many localities, owing not only to the improved economic state of the farmer, which makes possible better housing and a better environment generally, but also owing to the more extensive cultivation of the land, with the consequent better drainage and fewer collections of standing water in which mosquitoes can breed. The more general use of quinine as a household remedy, together with a commendable diminution of faith in widely advertised patent medicines, is probably also responsible for some of the improvements observed.

At the present time there are three principal, well-recognized areas in this country where malaria may be said to be at home. The largest area covers the whole southeastern portion of the United States, having for its western boundary a line drawn from Eagle Pass, on the Rio Grande, to Leavenworth, Kans., for its eastern boundary the Atlantic seaboard, and its northern boundary a line drawn from Leavenworth, Kans., eastward some distance north of the Ohio River and extending to the Atlantic on a line with the northern boundary of Maryland. Of the two smaller endemic areas, one includes a section of the northern part of New Jersey, southeastern New York, Connecticut, Rhode Island, and part of the State of Massachusetts. It is probable that the New England endemic area actually extends southward to the large southern area, of which it is really a part. The third recognized endemic area is in California, and includes the Sacramento and San Joaquin Valleys, which occupy a large portion of the central part of the State.

A striking illustration of the disastrous effect of malaria is afforded by the history of the lower peninsula of Virginia. Constituting, as it did, the earliest English settlement in America, and containing, as it does, excellent farming land, it is significant that this region is still practically uninhabited. On many parts of the peninsula there is hardly a family to 3 square miles. Though school histories do not mention the fact, it is on record that Jamestown was abandoned "because of epidemicals."

For the South as a whole it is safe to say that typhoid fever, dysentery, pellagra, and tuberculosis, all together, are not as important as malaria. The reason for this is to be found in the variety of ways in which malaria influences community welfare. There is practically no instance known of a white community thriving where malaria

seriously prevails. Those unfamiliar with the disease and who think of health only in terms of death rates, do not realize that although malaria causes a considerable amount of serious illness requiring the attention of a physician, this is only a small part of its ravages. Much more important are the cases in which the patient does not feel sick enough to go to bed, and, of course, does not consult a physician. These cases are extremely numerous and constitute a large item in the reduction of labor output. Recent surveys in the South show that the crop yields by plantations where malaria prevails is only a fraction of what it normally should be. Just at the time when the crops need most attention, chills and fever keep a large number of laborers from work.

In some sections of the lumber regions well-planned malaria control work has resulted in a marked increase in the output of lumber with practically the same overhead charges.

The prevalence of malaria is most injurious to children, and affecting them, as it does, at the time when they should be getting their growth and education, it gives them a permanent handicap in life. Competent investigators are of the opinion that the backward condition of the school children in the coastal plains of the Carolinas is almost entirely due to the prevalence of malaria.

In connection with the fact that the white population is prone to abandon regions where malaria is prevalent it must be remembered that this causes the disease to have an important sociological influence, especially in the South, for it results in large areas being inhabited almost entirely by negroes.

While malaria is primarily a rural disease it concerns cities, also, for experience has shown that the disease often seriously affects the suburbs. This was well shown in a recent health survey of Dallas, Tex., where in one suburb over 25 per cent of the sickness was caused by malaria.

It is well recognized that the prosperity of any section of the country is well measured by the amount of freight business done therein by the railroads. Applying this, we find that there is little railroad business in those sections of the South where malaria is very prevalent. The trains pass through these regions, but neither discharge nor pick up any considerable amount of freight. While this is of immediate concern to the railroads it deserves the careful attention of manufacturers, business men, and bankers throughout the country, for it reveals a large area susceptible of profitable economic development.

Theoretically the control of malaria presents no difficulties from the standpoint of public health officials and sanitary engineers. In perhaps no other disease is so much exact scientific knowledge available. The control of malaria is intimately related to the control of

the Anopheles mosquito. The habits and life history of this mosquito are well established. Practically, however, the problem of malaria control often presents great difficulties because of the financial outlay involved. In this connection it must be remembered that malaria is seven times as prevalent in rural communities as it is in cities and towns; that is to say, the rural communities with only limited populations directly concerned, and therefore with limited resources, almost invariably face a large area of mosquito breeding places to be dealt with.

With the successful demonstrations of what can be accomplished by well-planned antimalaria measures, a concerted effort should now be made to inaugurate an intensive campaign against malaria by enlisting Federal, State, and local governmental support, aided by individual and corporate interests concerned, in eliminating this health and business liability and in promoting the economic development of the affected regions.

We have here a program of subjects, rather than of papers. When the subject is called the gentleman designated on the program will open and others will be called for discussion. As a rule each gentleman joining in the discussion will be limited to 10 minutes. Name and station should be given so that our stenographer may know who is talking or the speaker will not get credit for his instructive remarks. This meeting will hold until 6 p. m.; we will then adjourn and meet at 8 o'clock at the marine hospital. The subject now to be presented is "Malaria investigations." Dr. Metz is requested to open the subject.

MALARIA INVESTIGATIONS.

C. W. Metz, Special Investigator.

The primary question, as I understand it, is: What are the things we do not know and what are the things we ought to know regarding malaria transmission and the eradication of malaria? To answer this in detail, listing each particular item, would be useless; such a list would be of value only if presented to you in printed form for your retention. Hence I will only try to bring out some of the general features and perhaps illustrate with a few examples.

I would like to leave with you three main points, which I will discuss in order:

First, the impression seems to have become common that we know nearly all that is necessary about malaria and its control, and that all we need to do is to apply what we know. This, I believe, is very pernicious. It is true that efficient means of malaria control are known, but it is also true that they are often very costly and that they are not at present adequate to control malaria except in restricted areas. This difficulty comes from several things, among which are a lack of knowledge of the malaria mosquitoes and the fact that we probably haven't discovered all of the best methods of control. This being the case, we should all consider ourselves students and be constantly on the lookout for new facts and new applications of known facts.

The habits of Anopheles mosquitoes, both larvæ and adults, need much more study. In this country it is especially important, I believe, to ascertain the differences in habits between the three common species, *A. quadrimaculatus*, *A. crucians*, and *A. punctipennis*. As an example of the importance of this I would refer you to the question of whether or not *A. quadrimaculatus* breeds in running water to any considerable extent. If *A. punctipennis* should prove to be unimportant in malaria transmission, its breeding places in running streams could be ignored and a great economy effected, providing this question were answered in the negative.

I would recommend that everyone connected with malaria work keep a notebook and record all his observations concerning malaria mosquitoes and malaria control. Get the Government publications on the subject and read the observations and conclusions of others. I think it is particularly important to keep constantly alert and

ready to note the bearing of everything you may encounter on the problems at hand. Valuable facts may be found accidentally. For instance, the use of creosote as a larvacide was suggested by the fact that two drops of beechwood creosote in a quart of water makes an almost violent nasal douche for man.

The second point I would like to emphasize is the value of the accumulated observations of many persons. Of course, investigations, in the main, ought to be conducted by men especially assigned to such work, but a vast amount of useful information can be acquired from the more or less incidental observations of men conducting control work in the field. As an example I might cite the need of observations on hibernation of larvæ. Relatively little is known about whether or not Anopheles mosquitoes hibernate in this country in the larval stage. Observations are needed from many localities. Another question that comes to mind is one that Dr. Carter asked me yesterday, "Does *A. quadrimaculatus* breed in cow tracks or small depressions of that sort?" I could not answer him. This seems like a small matter, but in some localities it may be very important.

Other important observations may be made by watching carefully for localities in which only one species of Anopheles is found, and recording fully all facts that might be responsible for this, such, e. g., as topographical features, nature of breeding places, kind of water, vegetation, natural mosquito enemies, etc. It would also be well to ascertain the prevalence and type of malaria present in such a place.

A question that I am interested in just now is: To what are Anopheles mosquitoes attracted? This may involve animals, chemicals, or physical objects, the purpose, of course, being to evolve an Anopheles trap.

Two other items come to mind in this connection. Places are sometimes found that appear suitable for Anopheles breeding but are free from Anopheles. Why? Record all features of such places. A valuable clew will probably be obtained in this way some time. Again, what is the effect of an intervening animal barrier, such as a number of horses, cattle, pigs, or sheep, between the source of mosquitoes and the place to be protected? Undoubtedly there is an effect, but how great is it, how much depends upon the kind of animals involved or the species of Anopheles, etc.?

All of these and many others are features that can profitably be studied by men in the field whatever their primary work may be.

The third and last point that I would emphasize is the magnitude of the malaria problem and the fact that no one method is sufficient for attacking it. Malaria can not be eradicated at once—at least with our present knowledge. No one measure, be it drainage, or oiling, or screening, or quininization, is alone sufficient. All these, and many

more that have not yet been discovered, could be used to advantage. So anything that will help, whether greatly or slightly, is valuable. A partial reduction of malaria leads automatically, by increasing prosperity and efficiency, to further reduction, and when a certain point is reached the process will go on of its own accord. So a fact does not have to be revolutionary to be important. A combination of relatively small measures may in the end attain the result.

Discussion.

Dr. Carter. Dr. Derivaux is not here to open the discussion. I will ask Mr. Mitzmain if he will tell us something about malaria investigations.

Mr. Mitzmain. Mr. Chairman, I really am not prepared to talk at length on this subject. Dr. Metz has already discussed many of the points brought up in his paper. What impresses me strongly is the fact that, probably due to our primitive organization, we are not equipped to disseminate the knowledge we already have. We ought to establish a headquarters, a clearing house, as it were, for this information. It should contain the literature and be a central place for the exchange of ideas. I think that every engineer who is at work on a specific problem should at all times keep his eyes open, making notes on any particulars that interest him and anything that he thinks will interest other members of the organization. He should impart to the others any information that he may acquire in the course of his work. It is most important that we establish a headquarters for the dissemination of just such knowledge. I would suggest that we appoint one or two members for the compilation of any stray facts that we can gather.

As to the literature, I want to correct one statement of Dr. Metz—with regard to the hibernation of larvæ. Dr. Griffitts has done a great deal of work on the hibernating of larvæ and we should all be acquainted with this information. We ought to hear from Dr. Griffitts concerning his work. We know considerable about the hibernation of larvæ. We have Dr. Griffitt's work on the subject, we have information from other sources that has not been published, and there is other literature which could be mentioned.

As to the matter of animal barrier intervention to control mosquito infestation, Ashburn at Panama has done considerable work on that. What appears in literature is more theoretical. I think that a great deal of good work goes begging. Of course war conditions have done a great deal to disarrange the routine of the organization. I think in the future we should keep posted on the needs of the problems before us. If we get anything of interest to ourselves, make a note of it—it may help some one else. If we run across anything that may appear

to be of interest to the rest of the corps, make a note of it—send it in to headquarters, establish a clearing house, so that we may disseminate this knowledge and develop it.

Dr. CARTER. I only want to say a few words in connection with this subject. I want to lay stress on the importance of observations, incidental observations. No matter how small, they may be of great value to some one in solving his problem. There are certain problems assigned by those in charge to one or two men. There are a great many other problems requiring solution and we must do what we can to help everyone in the field. The man in the field in Arkansas may find out something that may be of help to the man in Texas. In the spring of 1917, Le Prince, Griffitts, Williams, Derivaux, and myself were the only men engaged in malaria work. Now we have this large corps engaged on the many problems in malaria-control work. There is a long list of field problems, maybe 25 or 30. A list was made in the spring of 1917, before we went into the war, of field problems needing solution and I shall try to have a copy furnished to each engineer so that he will be watching out for data on the different problems. One man will get a particular point, another man something else, and no matter how simple, how trivial it may appear, give it in to the central office, the clearing house, and it may be that from these different notes we will derive a valuable conclusion on some important point. To illustrate, while working on impounded water, paying no attention to the biology of mosquitoes, we were able to determine a few points of interest. First, in the country "above the falls" in running streams, we never found *A. quadrimaculatus*, nor in small puddles or pools. We found *A. quadrimaculatus* practically confined to large pools of considerable width and depth. We found there was a great difference in the seasons in which these mosquitoes came. *A. punctipennis* comes early and stays late; *A. quadrimaculatus* comes later and disappears earlier. We found a great difference in their occurrence in residences; *A. punctipennis* almost never found in residences, *A. quadrimaculatus* in abundant quantities. We found one place in which, with the same production of the two species, there were six hundred times as many *A. quadrimaculatus* as *A. punctipennis* in residences. All of those things are worth knowing. They affect our antimalaria measures and hence are of sanitary importance. We solved these problems incidentally—kept our eyes open and put down what we saw. I am sure that if all of you know what problems need solution, at the end of a year, or two, or three, if you will make notes, sending them in to the central office, the information thus collected will be of much value.

Dr. METZ. Mr. Chairman, I would like to correct the impression (if I gave it) that no work had been done along the lines I men-

tioned. I am aware that a great deal has been published on a number of the subjects referred to. I only wanted to bring out the point that we still have a whole lot to learn. I am aware of Dr. Griffitt's work on the hiberantion of larvæ, but there is still a lot that we don't know about the hibernation of certain species of Anopheles. They may hibernate in the larval stage in Virginia, but do they hibernate as larvæ in New York, and how far west do they hibernate in this stage? It is not certain that hibernation in the South is the same as in the North. The same is true of other things. For instance, there is a good deal of information on the subject of animal barriers between breeding places and the place to be protected, but we can stand a much larger mass of information than we have. The fact that I wanted to bring out is that there is still much to be done on the various features discussed.

Dr. CARTER. The next subject on the program is screening of residences. As Dr. Taylor is not here I shall ask Mr. Snidow to open the subject.

SCREENING OF RESIDENCES.

H. W. Snidow, Scientific Assistant.

The control of malaria involves three general lines of procedure which may be termed by methods as community, family, and individual.

By the application of the community method malaria may be controlled over an entire section to which it is applied, all inhabitants sharing equally in the results. This is accomplished by eliminating Anopheles mosquitoes through the destruction of their breeding places by drainage and oiling. This method is applicable where sufficient combined funds and general community organization may be obtained and where the breeding areas are not so extensive as to make the per capita cost of their elimination uneconomical.

In cases where sufficient funds for complete drainage and oiling under a general community organization are not available, or where the breeding areas are too extensive to be undertaken economically, proper screening may secure protection to the occupants of such houses as are so constructed that they may be effectively screened. Owing to the general existing conditions this so-called family method is perhaps most extensively used.

In the absence of either of the above, individuals may secure a certain degree of protection through a systematic treatment of themselves with immunizing doses of quinine during the mosquito breeding season. This method alone is ordinarily of little value on account of the general personal dislike to taking quinine.

Observations have shown that a very large percentage of the screening done is not effective for Anopheles. This is due to three general reasons: (1) Attempts to screen houses which are so poorly constructed that they can not be effectively screened; (2) poorly constructed or improperly fitted screens using cloth of a mesh less than No. 16 and not painted; and (3) the construction of sliding or easily removable window screen frames which may be left open too often through carelessness. In either of the first two cases the intelligence or persistency of the Anopheles mosquitoes is certainly underestimated, and in the last case convenience has outweighed considerations of mosquito protection.

The first and fundamental feature in securing effective protection in screening is to apply it only to houses which have been properly

constructed or repaired with tight-fitting walls and floors and which are free from any cracks around the doors and windows. Contemplation, therefore, of a screening campaign in any community would involve first of all a careful investigation of all houses and a division of them into three classes: (1) Those already satisfactorily constructed, (2) those which may be repaired, and (3) those which may not be screened. Only the first two classes should be considered, and even then the second should not be unless the proper repairs are first made to the building.

In all cases, for protection against Anopheles, nothing less than a No. 16 mesh cloth or a 14-mesh painted should be used. Varying conditions may demand the use of bronze, galvanoid, galvanized, or black screen wire, or in the case of extremely salty atmospheres the different varieties of cloth mosquito bar. In all cases especial attention should be directed to the fact that in whatever material is used the mesh should not be larger than that of the standard No. 16 wire cloth.

The particular application of screening advocated may best be describing by quoting from the report of the Kress, Va., antimalaria campaign of which the author was director:

SCREENING OF HOUSES.

Owing to the uncertainty of any future effective drainage, apparent at the time of the malarial survey, thorough screening of all houses was made the chief recommendation for malaria control in Kress community. Consequently, prior to the beginning of constructive work, April 2, 1917, sufficient quantities of all materials had already been procured. These included only the best grades of No. 16 galvanoid screen wire cloth and of hardware, comprising door and window brackets, door fixtures, tacks, nails, etc., and lumber for framing and molding. With the beginning of the actual campaign this branch of the work was placed under the direct supervision of Mr. W. G. Cline, who had previous experience in the supervision of similar work at Wilson, Va. For practically all of the houses one general type of construction was employed and is as follows:

Windows.—The screen frames were made to cover the entire openings of the windows, fitting perfectly in the window frames just outside the sash. These were made of selected and thoroughly seasoned 1 by 2 inch pine strips and were strengthened at the four corners by iron brackets attached with screws. After the frame had been fitted to the window it was taken out and a sheet of screen wire cut to the proper size was stretched and tacked securely over it, after which the raw edges of the wire and tack heads all the way around were covered with strips of three-fourth inch half round molding. When completed these frames were inserted in the windows and held in position by nails or screws. For the colored homes and one white home in the community no frames were used, the wire being tacked instead to the outside of the window frames and afterwards covered with molding strips.

Doors.—Owing to the general inferiority of the machine-made types for mosquito protection all doors for this work were made by hand. For the upright sides of the frames carefully selected and thoroughly seasoned, 1 by 4 inch

pine pieces were used. The pieces across the top, bottom, and middle portions were made of 1 by 5 inch pieces. After the different pieces were fitted and nailed in the proper position four heavy iron brackets were attached at the corners and two iron braces at the ends of the middle support. The screen wire was then attached in the same manner as prescribed for the windows, and in addition several light strips were nailed across the bottom panel of the door frame to prevent the wire from being broken by persons carelessly kicking the door open. In fitting the doors in the door frames they were made to fit snuggly against stops or battens all the way around, sides, top, and bottom, on the inside, so that about a quarter of an inch space could be allowed between the edges of the door and the frames for swelling in wet weather. To insure the doors closing tight against the battens and remaining so at all times the long coiled springs were used instead of springs in the hinges.

Porches.—The frames for these were made of 1 by 2 inch pine strips run horizontally around the exposed sides, a sufficient distance apart to fit for supports of the edges of whatever widths of wire were used. Ordinarily these were three strips of 30 inches width, stretched horizontally. The frames for the doors in the front walls were made of 1 by 3 inch pieces, two placed upright the proper distance apart for the width of the door and a short piece across between the two to fit for the top of the door. The strips of wire were stretched ordinarily from the back walls at either end of the porch around to the sides of the door frame in the front wall, drawn as tight as possible, and nailed securely at the ends and along the edges with tacks placed about every 3 inches. The strips of wire were always cut a few inches longer than the distance measured in order to allow for the handhold for stretching while the last end was being nailed. After the screen wire was all attached, all the edges, seams, and ends were covered on the outside with molding strips, as in the doors and windows, except at the bottom, where a 1 by 6 inch baseboard was provided. When completed, the cracks between the weather boarding and the screen frames and others were filled with paper pulp made from old newspapers. Of the 32 homes, 29 were screened. In addition to the doors and windows, 14 of these included front porches and 3 both front and back porches, as tabulated on a following page.

When homes have open fireplaces, screens are needed either at the tops of the chimneys or covering the openings of the fireplaces or grates. Perhaps the simplest way is to place a section of screen wire over the top of the chimney and hold it in position with a layer of bricks and mortar around the edge on top. Chimney protection was not necessary at Kress, therefore it was not included in the above report.

Remembering that screening, like the proverbial chain, is only as effective as its weakest point, and also that human carelessness is perhaps the greatest factor in limiting the life of screens on any house, especial attention should be paid to these points. The weakest point in any screened building is the door. This because it is the one movable section frequently used and therefore subject to the different habits of carelessness common among people in general, and particularly children. The tendency of most persons in opening a screened door is to either kick against the bottom panel of the wire or shove against it higher up rather than pushing against the frame

of the door. Small children are also continually damaging screen doors by pushing against the wire or hammering on it with various things. In order to render screen doors as near fool and carelessness proof as possible, the following rules governing their construction should be observed:

1. To prevent warping the frame should be made of substantial carefully selected, light-weight material well braced with iron brackets at the corners. In order to add a double protection against sagging a wire support should be drawn diagonally across the lower half. This may be accomplished by the use of a double wire attached loose then tightened with a turn key until the desired tension is reached.

2. The section of screen-wire covering the frame should be cut sufficiently large to allow a lap of three-fourths inch all the way around and should be tacked on firmly with tacks not more than 3 inches apart. Afterwards moulding strips should be nailed on covering edges of wire and tack heads.

3. The lower half of the door rrame should be covered on the inside with a reinforcing section of the so-called hardware cloth, a coarse substantial wire screen with about a quarter-inch opening between the meshes. This will protect the bottom panel of the door from kicks and the carelessness of children.

4. A light strip of wood about 3 inches broad should be nailed across the door frame at about the height of a man's shoulders. This to push against when opening the door.

5. A satisfactory spring should be used to insure the door remaining tightly closed against the battens when not in use.

6. Two hooks or catches should be provided, one about halfway up to the top section of the closing side of the frame and the other near the bottom. The top catch may be used alone during the day, but at night both should be fastened. This will help to prevent warping.

7. In fitting screen doors in the door frames no attempt at edge fitting should be made. The door should be made to fit against a three-fourths inch batten all the way around on the inside and sufficient space should be allowed around between the edges and the frame for the door to swell in wet weather without scraping at the bottom.

CARE OF SCREENS.

Painting of screens should not be done frequently, and when it is done a very thin mixture should be used. It is reported that an application of banana oil each season is the best treatment. If galvanoid or galvex wire is used it is believed that no treatment will be necessary for the first four or five seasons. After that a very light

coat of paint or oil every season or perhaps every other season will be sufficient to prolong the life of the wire to 8 or perhaps 10 years, provided it has not received other damages than atmospheric corrosion. This of course does not apply to salt atmospheres.

SCREENING OF SEASIDE HOUSES.

The economical screening of seaside houses exposed to the extreme salt atmosphere is indeed a problem. No kind of metal screen seems to last long enough to make its use economical. Doubtless the best plan in these cases is to use the same precautions in constructing the frames, then recover them each season with the best grade of cloth screen material. Objections are continually raised to the use of cloth screens on account of their intercepting the air to a great extent, and also on account of their catching and holding dust. These objectionable features may be overcome by purchasing the particular kind of cloth screen (commercial name not known) which has a hard waxed surface similar to wire. Ordinarily this cloth comes coarser than No. 16, but by doubling it the desired effect may be obtained.

Itemized table of screening expenditures, Kress, Va.

House No.	Number porches.	Number windows.	Number doors.	Cost of wire.	Cost of lumber.	Cost of hardware.	Cost of labor.	Total cost.
1	1	11	2	$15.26	$6.00	$2.54	$8.40	$32.20
2	1	12	2	17.22	6.50	2.64	8.40	34.76
3	1	9	2	15.40	5.75	2.29	8.40	31.84
4	2	7	2	16.34	5.80	2.14	11.20	35.48
5	1	13	2	15.89	4.50	2.64	11.20	34.23
6	.....	5	3	4.83	3.00	2.46	5.60	15.89
7	.....	4	3	4.34	2.70	2.26	5.60	14.90
8	.....	4	3	4.34	2.70	2.26	5.60	14.90
9	.....	5	3	4.83	3.00	2.46	5.60	15.89
10	1	4	3	11.13	3.95	2.21	7.00	24.29
11	1	7	3	10.57	4.10	2.31	7.00	23.98
12	1	6	2	9.62	3.85	1.99	7.00	22.46
13	1	6	2	9.62	3.85	1.99	7.00	22.46
14	1	6	2	9.62	3.85	1.99	7.00	22.46
15	2	12	2	22.22	6.90	2.69	14.00	45.81
16	1	12	2	16.34	6.00	2.44	8.40	33.18
17	2	3	2	21.17	5.85	1.59	11.20	39.81
18	1	4	3	15.40	4.35	2.46	7.00	29.21
19	1	4	3	15.40	4.35	2.46	7.00	29.21
20	1	4	3	15.40	4.35	2.46	7.00	29.21
21	1	10	3	17.64	6.80	3.01	11.20	38.65
22	.....	3	3	3.85	1.95	2.21	2.80	10.81
23	.....	1	3	.60	.75	1.81	2.80	5.96
24	.....	7	1	4.41	2.75	2.27	4.20	13.63
25	.....	3	1	2.97	1.40	1.27	2.80	8.44
26	.....	5	3	3.95	1.30	1.91	2.80	9.96
27	.....	5	3	3.95	1.30	1.71	2.80	9.76
28	.....	5	3	3.95	1.30	1.71	2.80	9.76
29	.....	2	1	1.57	.45	.67	1.40	4.09
30	.....	2	1	1.57	.45	.67	1.40	4.09
31	.....	5	2	4.93	2.20	1.59	5.60	14.32
Totals	20	186	73	304.33	112.00	65.11	200.00	681.64

NOTE.—Galvanoid screen wire was used in the above and purchased at a cost of $3.50 per 100 square feet, wholesale.

Discussion.

Dr. Carter. Dr. Griffitts is asked to open the discussion on this subject.

Dr. Griffitts. Mr. Chairman, the first thing always to be considered in screening houses against mosquitoes is the very thing I believe that Mr. Snidow left out, i. e., that size of the mesh to be used in the screen. Of course it is generally understood that you should use 14 to 16 meshes to the inch against Anopheles—14 will turn most of them. Unfortunately, however, the merchants who buy screening material do not know which is the best to buy. They purchase stuff that will turn a horsefly but not mosquitoes. I have had some experience and made some observations on screening. Referring to Dr. Metz's paper, in which he suggests that we make notes on the habits of the mosquito, I shall go further than that—never miss an opportunity to make a note on anything that has to do with malaria-control work.

On one occasion while working with Dr. Carter and Mr. Le Prince on impounded waters in South Carolina we were fortunate in securing a boarding place with an up-to-date farmer. We had his place completely screened, including the fireplace, and while examining the fireplace screening I noticed in a room on the second floor that there were about 15 to 20 *Anopheles quadrimaculatus* behind the screen in the fire place. They had come down the chimney to the second floor.

In the year 1916, at a lumber-mill village just outside of Portsmouth, there was lost an aggregate of over nine years' time on account of malaria. It is a very flat country, difficult to drain, with many breeding places for the Anopheles. We started control work late in the season, too late to enable us to control the situation by drainage. We decided to try all plans, including screening and giving sterilizing doses of quinine. Fifty per cent of the property was owned by the lumber plant, and we had no difficulty in getting them to screen, but the other houses belonged to the negro laborers. Screening to protect the white man is somewhat different from screening to protect the ordinary negro, and sometimes in the case of the negro you begin to doubt if it is advisable even to try. The county agreed to pay for the screening material, and the Public Health Service was to furnish supervision, including expert carpenter supervision. We screened practically every negro shack. We made the screen doors out of material furnished by the lumber company. In screening the negro cabins we simply nailed the 14 or 16 mesh screening material to the base of the top sash, held down the netting with a one-half or one-quarter strip, and nailed it to the baseboard of the window, so that the upper sash could not be used

FIG. 1.—ILLUSTRATING SCREENING, KRESS, VA.

FIG. 2.—SCREENING, KRESS, VA.

at all. The negroes, as a rule, do not use the upper sash. The doors were made of light material, well seasoned. I believe a great deal of the sagging of doors comes from the use of heavy material. I would like to say that at the end of the second season scarcely a door in the whole village had warped. In my opinion it was due largely to the fact that we used light material. Each corner was braced with a triangular block of the same material as the door. We put a "kick board" on the inside of each door just where the toe strikes, which is a great protection. Most people who have anything in their hands will kick the door open. We even found some of these "kick boards" kicked off. We also put a board across the door at the place where one usually puts his hand when opening the door. I think that these "kick boards" go further to protect the efficiency of your screen door than anything else. As to the matter of hinges, it is not so important if the doors are light. We used cheap hinges we bought in the locality. I believe the weight of the door is the most important factor in connection with sagging.

It is difficult to get carpenters who won't fuss about edge fitting. It is more important to get a door that will not warp than to worry about the edges fitting. Make your doors close against something instead of trying to fit edges. During the war we have had much opportunity of employing the screening method of malaria control. No doubt most of us have had opportunities of inspecting screening, and in some instances we have been asked to advise camp authorities on screening. At Quantico we were asked to advise the camp authorities about screening, and I believe we gave them material assistance.

As to the matter of screening fireplaces and chimneys, I believe the method Mr. Snidow spoke of is probably best. This method was first suggested in 1917. Chimneys are screened easily and effectively by this method.

Dr. Carter. Mr. Tarbett is next on the list.

Mr. Tarbett. Mr. Chairman, screening measures carried on in the Lonoke district about Ebert's Field were under the direction of Dr. Geiger.

The impossibility of complete control over mosquito production, due to the location of rice fields within the zone, made it necessary that all known malaria control measures be instituted, including screening.

This zone had a population of about 2,400.

In February an inspection was made of the sanitary conditions and screening of every piece of property in the zone. This inspection showed that not 10 per cent of the buildings were properly screened. All buildings were classified into three groups—good, repairable, and uninhabitable. The buildings in the last group were such that screen-

ing was impossible and these were ordered vacated and remained so throughout the season. Rules as to screening were promulgated and a time limit set for completion. Specifications required all screens to be of 16 or 18 mesh. All buildings were obliged to be screened and those public buildings within which gatherings might take place at night were required to have in addition vestibuled screened doors. All screening was done by and at the expense of the property owners, various types and methods being used. A monthly inspection of the screening was made and all property owners were required to maintain same in good condition. The screening of some of the small negro cabins, while crude, was remarkably good.

As to the screening of the buildings within the camp: All buildings except the hangars and work shops were well screened, all living quarters and offices having vestibuled screen doors. During construction, advice as to proper screening was given the constructing officer.

Dr. CARTER. We would like to hear from Mr. Van Hovenberg relative to screening on the railroads.

Mr. VAN HOVENBERG. Mr. Chairman, the railway on which I work is divided into two parts, the Texas line, and the Arkansas and Missouri lines. I have here a table showing hospital admissions for malaria treatment from the bridge and building departments of the St. Louis Southwestern Railway for the years 1915–1918 to illustrate result of screening applied to cars in which these men live.

	Number patients admitted.			
	1915	1916	1917	1918
Texas lines (bridge and building employees)	38	31	16	1
Arkansas and Missouri lines (bridge and building employees)	49	43	21	10

These cars were first screened in the spring of 1917. You notice the remarkable falling off, due to the screening of the cars for 1917 and 1918. This is my only experience with screening as an antimalarial measure. In addition to the screening we gave the bridge and building men on the Texas lines quinine free of cost, beginning in August, 1918.

In our railroad work we are contemplating using the heavy galvanized wire, with large mesh, to protect the 16-mesh screen, thus making it difficult to break through the screen. The same applies to screen doors. I would like to have some one tell me how to apply a screen door to a box car and make it mosquito-proof.

Mr. GRIFFITTS. Mr. Chairman, we should make a study of screening, and if possible come to a determination as to what kind of screening material is best suited for the different sections of the country, which is the best on the seacoast; which is the best inland.

In this connection we screened one house with cloth, (such as Palmer of McLain screening cloth), just to see how it compared with other screening material as to durability. We found upon inspection about 10 days ago—22 months after the cloth had been put on—that it was the best-screened house in the town. This is not where the atmosphere is highly charged with salt. The only fault we found with any screen in this house was in one room where a toy engine had been pushed through it. If we could find some way of protecting that screening from mechanical injury it would have more in its favor. It would be especially advisable to use it on the coast. In conversation with a man at Virginia Beach, I learned that he had used this cloth to a considerable extent and found it satisfactory. It is much cheaper than the other materials. He stated that in an attempt to prolong the life of some of his galvanized material he had painted all of his screens except two. A year or two later when he was replacing the screening he found that the two that had not been painted were the only ones in the house that did not need to be replaced. In other words, he thinks if you paint galvanized iron you shorten its life.

Mr. Le Prince. Mr. Chairman, I would like to ask regarding the screening of the top of the chimney. In all cases, did the screening remain intact, or did the wires rust and decay? Are we sure the netting will last the season through?

Mr. Griffitts. Mr. Chairman, I am not sure as to that. We should try it out.

Mr. Le Prince. Mr. Chairman, in 1904, I had occasion to ask for bids for copper-bronze screening in large quantities and when I asked the representative of the different firms how long the screen would last, they gave me unsatisfactory answers. Some stated two or three years, some six or seven, and one man said nine years. I asked this man if he could give me a list of places where it had lasted nine years. It is needless to say that he was unable to give me such a list. It is probable that in 1904 the firms who made screening material had little idea as to its lasting qualities, and they knew very little as to what causes the decay of screen wire. Here is an industry in which hundreds of thousands of dollars are involved each year, and it is important that there should be some light on the subject, some information as to the best composition or alloy. The study of the decay of our galvanized-iron mosquito screening is important. People have to pay for screens and they are entitled to know what they are paying for. I don't know how much is paid out for screening each year in the United States, but I do know that the amount is large and is increasing annually.

If we consider the screened houses all over the country, how many are effectively screened and kept in that condition? I think I am con-

servative in stating that eight out of every ten screened houses are not effectively screened. I do not think that 2 per cent of the people who pay for screening of houses ever think of inspecting that screening at regular intervals to see if they are getting the results that they are paying for. Screening has an important bearing on malaria control. The Anopheles appear to have more sense and more desire to get into a house than the other mosquito has. So when you screen in a rough way, it will keep out some mosquitoes which are a pest and do not carry malaria, but does not keep out the Anopheles. This is important.

Malaria is a rural disease. The farmer is the one who suffers mostly. In the region where there are many cases of malaria, as a rule, the houses are not close together. There is not sufficient population to pay for extensive drainage measures. We must have some other means of protecting that community. Screening becomes one of the most important measures. An important factor to be determined is, what is the best way of getting the people to keep that screening intact? When we learn that we are going to have less malaria than we have at present. Many of our farmhouses are screened, but not effectively. The farmer makes the investment, but he is not getting proper return on it.

It has been stated time and time again that it is no use to screen the negro quarters on the plantations—that it can not be done. I can not discuss that as a whole, but in Arkansas, in the rice-field towns, the negroes are not only living in effectively screened homes but they are paying for such protection themselves. The probable cost is 50 cents per yard, and balconies are being screened as well as doors and windows with 16-mesh galvanized iron screen. So the statement of the owner that it is no use to screen the negro quarters doesn't hold. In that locality the negroes are doing it themselves and paying for it.

In our most malarious districts the farmers are paying from $5 to $20, $30, $40 an acre for clearing land, and they are losing a large amount of money, due to the fact that malaria is present among their own families and the entire locality. By effectively maintained screening they can save much of the money that is now being wasted.

The fact of the necessity of screening for protection against the mosquito has been brought out. I think you will find the defective screen door is the main entrance for the Anopheles mosquito, more important than the window. The protection afforded by a well-made door is most important. How many screen doors have you seen where the screening is thoroughly protected? Where little children are in the house, appropriate protection must be placed on the screen door so that they will not lean against the screen. You will be told time and time again that screening is no protection against mos-

quitoes. It is not the screening that is defective, but the procedure of the person who does the installation. The unsatisfactory results are generally due to absence of protection of the screen from abuse, and also because minor defects or breaks in the screen are not attended to promptly.

Regarding malaria in the aviation camp at Lonoke, Ark., the buildings there were screened, and possibly a few of the aviators who did try to protect themselves from malaria kept under screens after dark. There are two points regarding protection by screens which should be emphasized.

First, if the screen door used is on the side of the house from which the prevailing wind blows, the number of anopheles entering the house will be far less than if the door used is on the leeward side of the house. Now the second is this—if one person only uses the screen door after dusk a certain number of anopheles may enter when that person enters, but if, say, 30 people approach the house at one time and use the door, entering the house, and in addition are careless in not closing the door promptly, as is apt to be the case, the screen door is open for a considerable interval. The house is then no longer properly protected by screening. To illustrate this point—on the Isthmus of Panama we slept 60 men in each barrack, and the doors by actual count were kept open as long as 4 consecutive minutes during the morning and evening hours when the men were entering the building. On one occasion over 200 anopheles were caught in one of those screened barracks with perfect screening, when the doors were thus kept open.

Mr. Shaw. Mr. Chairman, at Lake Charles, La., according to the old residents, the malaria rate was very high prior to the general use of screening. Although ordinary methods of screening were used, which, from a malaria-control standpoint would well bear correction, it has been very effective in the reduction of the number of cases.

A malaria history was secured by a house to house canvass of the outlying towns of this section, and it was found that the malaria rate of the screened houses was 50 per cent lower than the rate of the unscreened houses.

I would like to ask Mr. Griffitts if any objection was made to the cloth screening on account of its interfering with ventilation?

Dr. Griffitts. That objection was made, and also that it collected dust more than the other screening. It has a larger mesh than the metal screening.

Dr. Stiles. Mr. Chairman, it so happens that I have had considerable experience with this cloth screening. One very serious objection is that it sags very quickly. The cloth screen can not be kept taut and, therefore, it makes a great eyesore to a nice house. Another point—it gathers a tremendous amount of dust and the housewives in dusting

it off enlarge the mesh, so that the screen does not carry out its intention. The third and very serious objection is that it cuts off the ventilation much more than the wire screen. I have had occasion to compare the two for a number of years on some cottages at the seashore. The cloth screen is particularly objectionable in a residence where the roads are of the yellow-clay type.

Dr. CARTER. Why do we screen? If you can eliminate breeding places so that the Anopheles mosquitoes are not present, screening is not necessary as a remedy against malaria. It is better not to have the mosquitoes—to control the production, provided you can control the production, than to prevent the entrance of the mosquitoes into the houses. But there are many places and many conditions in which it is not economical or practical to control mosquito production. In such circumstances, screening is indicated. Take, for instance, the town of ———; I looked the town over and estimated that to eliminate the Anopheles mosquitoes it would cost $1.48 for every dollar of assessed property in the town. This was obviously financially impossible, but that town could be screened at very much less than that and get good protection against the mosquito. Screening is an excellent makeshift and is advisable for control in some places, under some conditions, where the prevention of the production of the Anopheles is not advisable or practicable. You can not afford to pay for protection against malaria more than it is worth. That is the reason for screening. Mr. Snidow has not given himself credit for the excellent work he has done, for the results he had obtained at Kress. Mr. Shaw spoke of conditions at Lake Charles, La., and the little outlying town where screening was used. The history in these places showed that there was 50 per cent less malaria in the screened houses than in the unscreened houses. That is the result some one asked for. Screening alone was relied on in these places.

Referring to the material used in screens and how long it lasts, in 1903 I screened the marine hospital in Baltimore, using the so-called rustless iron. The first renewal was in 1914—11 years later. None of these screens lasted less than 10 years. They were not painted until the fourth year, and then they were painted with a very thin coat every second year; where protected by galleries, every third year. At the Chandeleur Islands, from 1890 to 1893, I found that the double bobinet lasted as long as any iron I could get. Ordinary iron, painted, lasted only three months. The bobinet will last a season through. Of course, it depends where you are. The life of a metal screen is very short on the seacoast on account of the salt in the air. At Colon we had a hospital that would have kept a gang of carpenters their entire time to keep it well screened. It was situated on a reef over the sea and the salt water was on the screen all the time. Waxed cloth in

such a case would have been more lasting than anything else. We should make a study of screening. I do not think that 2 per cent of the screened houses in the United States are perfectly screened. I will say this, that I saw not a single cantonment that was even well screened. The best was at Quantico.

There are two reprints issued by the Public Health Service on screening—one by Von Ezdorf and one by myself. They are both well worth your study. Here are a few principles to observe: (1) The size of the mesh is important, and is indicated by its number, No. 16 having 16 meshes to 1 linear inch. No. 14, painted, is just as good as No. 16. (2) The screens put in the window should be so constructed as to be movable only by the carpenter. If the housewife can leave the screen out she occasionally will, and the colored girl will frequently leave it out. Therefore, so construct the screen that it can be taken out only by the carpenter. (3) Doors should be fitted so as to shut against square surfaced heavy battens. No single Army camp that I saw had a screen door with a square surfaced batten at the bottom. The batten should go entirely around. (4) Doors should always open outward—always—else the mosquitoes which are settled on them will be driven into the house when they are opened. (5) It is almost impossible to render a double door mosquito tight. A double door has no place in a house we are trying to keep free from mosquitoes. (6) Mr. Snidow figures on an automatic catch on the middle of the door. The main advantage of an automatic catch is not so much to hold the door tight as to compel you to take your hand and open instead of your knee to push it open. If any fastening is put at the middle of the door that compels you to open with your hand and not with your foot, protection is given to the screening. If Mr. Van Hovenberg will read Von Ezdorf's reprint on screening, he will get ideas for making screen doors for box cars. If you can put an automatic spring at the middle of the door, do it by all means. It is not always possible. These are roughly the principles on which screening is based.

Mr. Snidow. Mr. Chairman, one point overlooked in my paper and which may be worth mentioning: In certain cases of screened porches the nailing of a wooden strip around the edges for the bottom support of the screen wire interferes with the natural draining off of the rain water which may blow in during rainstorms. One way to provide a means for this water to drain off is to bore a row of auger holes through the floor just inside the bottom strip and protect these holes with pieces of screen tacked over them or underneath if there is room to get under the floor.

Another point, in towns where houses are lighted electrically, there are usually porch lights, and generally in the middle of the porch. These lights naturally attract night-flying insects other

than mosquitoes, therefore lights at either end rather than the middle have a tendency to attract toward the sections away from the door, where access may possibly be gained.

In regard to the material and size of mesh for screening I am sure I mentioned it, but I will repeat. Nothing less than a No. 16 or a No. 14 painted should be used. The galvanoid screen wire is perhaps the best. It appears to be a galvanized wire treated with an extra coating of some kind of a metallic paint. If you burn a piece of it over a lighted match you get the odor of paint. Furthermore, it is more stable or rather it stretches over the frames more smoothly without warping or sagging, therefore presents a very much better appearance than other kinds.

Dr. CARTER. The next subject for consideration is "Railroad malaria problems," by Mr. Van Hovenberg.

RAILROAD MALARIA PROBLEMS.

MR. VAN HOVENBERG, SANITARY ENGINEER.

Malaria problems on railways may be described from the standpoint of the operating officer, and from the standpoint of the responsibility of railways in general to the malaria problem.

Problem of the operating officer.—It is the duty of a railway official to serve the public and to earn dividends for those who have intrusted their money to him. He must give his attention to every factor that hinders his service or decreases his dividends, and, conversely, must accept any innovation that will increase service and revenue. His first consideration would be to secure efficient labor since his greatest outlay is for labor, and because efficient labor builds well, and well-built tracks and equipment mean economy of operation.

The high rate of malarial infection among southern railway employees plays a great part in labor conditions along the lines. A survey of railway hospitals extending over parts of the States of Missouri, Arkansas, Texas, and Louisiana during the past four months, has shown that at least 30 per cent of all patients entering these railway hospitals for medical treatment were diagnosed as malarial patients. This is the yearly average. During the malarial months the rate will reach as high as 60 per cent. In addition to the hospital admissions, some railway surgeons estimate that from five to ten times as many employees are treated for malaria in the cities and towns along the lines, who are never sent to the hospital. There are also many employees who go to private physicians, or who doctor themselves with quinine or chill tonic, so as to be able to stay on the pay rolls.

The cost to the railway of a case of malaria treated at the hospital may be estimated with reasonable assurance. Likewise the cost of a case treated by a local surgeon along the line. My opinion is that the loss to railways through those men who suffer with malaria but who continue to work and give a feeble portion of their energy in return for good wages, is many times larger than the loss through the known cases of malaria that are treated by the hospital or local surgeons.

Without going into details, I estimate a case of malaria to cost $50 to the railway that operates its own hospitals. A road employing

10,000 men would have about 600 malaria patients a year in the hospital. These patients would range from track laborers to general officers. On such a road we might figure on 600 hospital cases at $50 and 3,000 cases treated by local surgeons at $35 per case, or a total of $135,000. This sum is equivalent to the wages of 135 men for one year at an annual wage of $1,000. I know of one railroad in the South with an average of 600 employees. During the year 1916, 93 of these men entered the hospital for malarial treatment.

To arrive at a factor by which the cost of the known cases of malaria may be multiplied to give the ultimate cost of malaria to a railway, we must consider many factors, among them the following:

(1) As above, the enormous cost to the road from men working while suffering with malaria and who are returning very little energy for their wages.

(2) The immense overhead charges occasioned by the turnover of labor.

(3) The cost of replacing skilled workers by others not so efficient measured by decrease in quality and quantity of product; combined with the cost of transporting the sick employee to the hospital and of carrying another man over the line to relieve him.

(4) The cost to the roads through damages paid for loss of life or limb by reason of employees injured on duty, while working about moving machinery, on top of cars, while coupling cars, etc., while suffering with malaria and physically unfit for duty.

(5) The loss to the railway through inefficiency of workmen who are discontented or worried because of illness in their families, brought on by residence in a highly malarious community.

(6) The loss occasioned by delay in completion of construction work because of malaria among the laborers.

(7) The losses through accidents brought on by bad roadbeds.

(8) There is also the complication of malaria in general diseases and in surgery. It is estimated by some railway surgeons that at least 50 per cent of the patients who enter hospitals for other than malarial treatment require such treatment. This is true even in the surgical wards.

(9) There is the great economic loss to the railroads through a decreased freight and passenger revenue on communities that are highly malarious. The prosperity of a railway depends on the prosperity of the cities and towns served by it. Sawmill towns that are highly malarious are not prosperous. The mills are often closed, or some departments, because of scarcity of labor. The output of the mills is decreased accordingly. The railways in such circumstances lose through not having the lumber to haul.

In my opinion the problem of malaria on railways outweighs every other consideration of health among railway employees and their

dependents, and I can even assert that malaria is costing some of the southern railroads more by far than accidents. Yet we have well-organized claim departments with highly skilled officials in charge. We have national and State legislations compelling safety appliances. We have "safety-first" departments that have proven very wise investments for railways. But we have only one railway that I know of that has a department giving all of its time to the control of malaria among employees and in the cities and towns along the line. This railway is the St. Louis Southwestern Railway System.

It is true that some roads have recognized the malaria problem and have taken some steps toward the relief of their employees. These steps, however feeble, have been in the right direction. I have yet to find a railway official who does not fully appreciate the importance of malaria control. I believe we are on the threshold of extensive malaria-control programs for practically all the southern railways.

Now, as to what malaria control on a railway means. A railway with 10,000 employees would operate, say, some 1,800 miles, through possibly several States. Its employees are drawn from all parts of the land. Some are imported from foreign lands, such as Italy, Greece, and Mexico. They may either be highly infected or easily susceptible to malaria. Some employees live in the towns in which they work in shop or office. Others live on outfit cars that are moved from point to point over the line. Many employees work at night. Employees, such as trainmen, are obliged to sleep in hotels and rooming houses, away from their homes, just as duty calls them. The time, place, and condition under which these men live enters into the problem of malaria control.

To effect control at a minimum of expense, we would naturally begin with those departments of the railway that furnish the most malaria, or which lend themselves readily to control. We find generally that the section men, extra gangs, bridge and building department men, trainmen, and shop employees furnish 90 per cent of all malaria patients entering the hospital. The section men make up 30 to 40 per cent of the road's employees, and furnish about 40 per cent of the malaria. The extra-gang men, bridge and building employees, and other floaters make up from 12 to 20 per cent of the employees and furnish from 15 to 25 per cent of the malaria. Shopmen make up about 20 per cent of the employees and furnish from 10 to 20 per cent of the malaria. The trainmen will furnish possibly 5 per cent of the malaria.

The methods of control for the above-mentioned departments would vary. Section men would be protected by screening their homes, by use of quinine and the mosquito nets. The bridge and

building departments men and the extra-gang men would be protected by screening of their outfit cars, by use of quinine, and by instruction in the swatting of mosquitoes that get into the cars. It will be found more economical to protect the shop employees by eliminating the breeding places of the Anopheles mosquito. The St. Louis Southwestern Railway has offered the services of its sanitary engineers to the owners of lumber mills along the railway to direct malaria-control work, and has provided a fund to be shared with cities in general campaigns against the malaria-bearing mosquito. In these ways the railway will benefit, both by protection to its employees and by the increased revenues that will come from prosperous communities.

THE RAILWAYS' RESPONSIBILITY TOWARD THE MALARIA PROBLEM IN GENERAL.

First, as the builder of breeding areas for mosquitoes, by impounding streams for the purpose of water supply, usually within city limits; by maintaining borrow pits that do not drain; by placing culverts at too high an elevation; by discharge of waste water from stations where sewers are not available; by construction of stock-watering tanks; by use of unscreened fire barrels and buckets on platforms; by improper drainage from refrigerator and ice-filling stations; by not keeping their engine water-supply tanks in repair; and by tapping the ground-water veins in cuts. In fact, building the roadbed on a railway is very much a problem of impounding, draining, and crossing water, and is a problem that lasts as long as the railway.

Again, the railways are agents that introduce malaria into communities by importing laborers from malarious districts or countries. There is also the domestic problem occasioned by transporting negro laborers from the South for railroad work in the North. This occurred in great numbers during 1917 and 1918. The railways tend to spread malaria by bringing large numbers of infected laborers into cities where work is being done; by housing men in sleeping cars that are not properly screened; by locating shops in the worst possible localities from the standpoint of malaria control; by maintaining waiting stations for the public that are not screened; by carrying the adult mosquitoes in passenger and freight cars from infested districts into areas free from malaria, and by being the agent that carries sightseers from nonmalarious districts into the malarial hotbeds.

The southern railways should be vitally interested in the malaria problem. A large part of the 2,000,000 employees of railways may be found in the so-called malarial States, or in the States having the

malaria-bearing mosquito. The cost to the railways from the sapping of the energy of hundreds of thousands of laborers by chills and fever is certainly tremendous. The problem is worthy of the consideration of any railway executive. It is a strictly business proposition, and one that will pay enormous dividends for the small outlay involved. One Federal manager of railways told me recently that in his opinion it would be decidedly a good investment for his lines if it were possible to eliminate 1 case of malaria for every 10 miles of track. This can be accomplished easily. It has been demonstrated on the St. Louis Southwestern Railway that malaria control is a wise business move. In consequence of two years' experience, this road has trebled its original appropriation for malaria control. The door is wide open for cooperation between the railways and the municipalities. The ever-increasing interest shown by railway officials in the South convinces me that malaria control on railways may soon become one of the most important provinces of the sanitary engineer.

Discussion.

Dr. Williams. Mr. Chairman, there is a question I would like to hear discussed in connection with the railroads and malaria. It may not be exactly in line with those just touched on, but there is a question coming up in different places which requires a course of procedure not yet determined. I have in mind some matters at the station with which I am connected. It is difficult to tell what the railroads are going to do. There are instances, any number of them, where the railroads have actually produced a certain amount of malaria and mosquito breeding. They have put their culverts in too high. In building roadbeds they have impounded waters running along marshes. They have so conducted their operations as to turn a marsh into a fresh-water pond—a pond heavily overgrown with vegetation, which breeds mosquitoes to an enormous extent.

The appropriation made was based on the entire amount of work to be done. It is intended to do work on private property as well as anywhere else. The money is raised by taxation, and there is no intention of charging such work against each property owner, as they have paid their share of taxes. Later there is found an enormous amount of needed work along the railroad right of way. Shall the railroads bear the expense of this work or shall it be done with the appropriation? There is not sufficient money at hand to include the railroad work. I would like to get ideas on this subject and hear the experiences of others on this question. I am requesting the railroads to do an enormous amount of work, and they are not showing much cooperation.

Dr. Carter. I will ask Mr. Harrub to debate this question.

Mr. Harrub. Mr. Chairman, I had a similar experience with the railroads in Jacksonville. We had on the east side of the city a marshy, swampy ground. The railroad people had built a terminal along the river and had filled in along the river bank. That part was all right, but occasionally they had to dredge out their docks and pumped the dredgings in back of the filled land and kept it in a continual mess. That cut off the natural drainage course there. The city had been trying for a number of years to get this swamp cleaned up, and had finally succeeded in getting a ditch dug through the high ground along the swamp which connected the upper end of the swamp with the lower end, but had no outlet; consequently, they did not get rid of their swamp. I wrote to the railroad manager, and in my first letter I went into considerable detail concerning the necessity of and reason for the work. He took no interest whatever at first, and finally I wrote to the bureau and asked them to take up the matter with the Director General of Railroads. However, while awaiting an answer to my letter I got a more favorable reply from the railroad people. They sent a man down there and I showed him what was wanted. As a result, we got $10,000 worth of work out of that railroad. Some of the swamp was below tidewater, but we got a good ditch there and the area is cleaned out.

We had the same experience in regard to culverts that Dr. Williams and Mr. Van Hovenberg spoke of. They cut down until they found water and built a culvert above it. In some instances they banked right straight across the natural drainage courses and cut them off entirely. I succeeded in getting them to lower two culverts.

The first swamp that I spoke of ran over into another railroad property and I got this road to put in $2,500 worth of work. It was a much easier matter to get cooperation with the second railroad than with the first.

At one of the shipyards the Florida East Coast Railroad had dug some borrow pits in order to build embankments. These pits were located on both sides of the main entrance to the shipyard. I wrote the manager to ask that their engineer adjust this matter. He came on, made an inspection, drew up a sketch, and made a report to his manager that things seemed to be all right. The manager wrote me to that effect. I answered his letter, telling him that his engineer had gotten a wrong impression of the situation as to the necessity for the work; also that in the sketch sent in by his engineer the water was running up hill instead of down hill, and suggested that if he looked into the matter more thoroughly he would find that the sketch I was sending gave a true picture of the conditions. He could either drain or fill. The estimate made by his engineer was between two and three thousand dollars. My estimate was $500 and it covered the cost to the railroad. After receiving my letter and sketch the manager

replied that his engineer had been instructed to go ahead in accordance with my plans. We secured good cooperation from the railroads. Altogether we got $13,000 in work done.

Mr. Frank. Mr. Chairman, the Louisville & Nashville Railroad traverses the entire length of the Mississippi coastal district and forms for considerable distances an artificial dam or dike, with many culverts neither low enough nor large enough. Within the past six weeks I have the promise of the district superintendent at New Orleans that if I will make definite propositions for each problem, accompanied by blue prints, etc., he believes he can get the chief engineer to give his consent to the work. There will be considerable work to be done by the railroad but Mr. Bose, the superintendent, has shown an attitude of such entire cooperation that I believe the work will be done.

As to the relation of the railroads to private property owners and to antimalarial drainage, I do not believe it is necessary to regard them in the same way. They are common carriers and, therefore, public servants, and I believe that they should be, and will be, willing to bear the entire responsibility for antimalarial drainage in districts where their artificial structures were responsible for malaria in communities along their rights of way.

Dr. Carroll. Mr. Chairman, I must say that we have always been able to secure cooperation from the railroads. The railroad engineers have always been willing to lower culverts whenever necessary.

Capt. Gies. Mr. Chairman, we have had considerable difficulty from a mosquito-breeding standpoint with the railroads which radiate out from New York. They have in many cases cut across strips of salt marsh in building their right of way, without proper culverts, thus cutting off main outlet creeks and impounding water. They have also placed culverts too high in many cases, thus interrupting drainage, and in some instances dug out borrow pits for material for building the right of way—the borrow pits becoming pools or ponds after heavy rains. We have found that to remedy these conditions it is simply a question of getting hold of the right railroad official; usually the higher official to whom the matter is brought the better the results obtained. If such mosquito-breeding nuisances are brought to the attention of the general superintendent, the chief engineer, or the division engineer, we have usually gotten quick action in abating the mosquito breeding. It is advisable to point out to these officials that most of these breeding places are artificially-created nuisances, as a result of the railroad's failure to consider the chances of mosquito breeding in the original construction of their right of way. Point out to the railroad officials very

definitely what you want done, either by getting them directly at the spot where the nuisance exists or by accompanying correspondence with a clear-cut sketch or map showing exactly the nuisance and your desire as to its abatement. By following this procedure, we have been able to get large amounts of work done by the railroads in the placing of proper culverts, the building of tide gates and the filling or drainage of borrow pits, swamps, and pools on or immediately adjoining the railroad's right of way.

Dr. GRIFFITTS. Mr. Chairman, I advocate treating the railroads like individuals. I think they are corporations with souls. We have two different types of railroads in Virginia. The one has always done, and I believe always will do, everything it possibly can to better health conditions; the other the opposite. You are always able to get better results by going to the high officials. In regard to the railroad that leads west from Norfolk, I had written letters time and again, and received replies that the matter would be taken up, but could get no decisive action. On one occasion I got on the train and went to the general manager. I got a promise from the officials to come down there and do what we considered necessary to correct conditions. The next week an engineer and 50 men came with instructions to report to me and not to leave until the work was done satisfactorily. The trip got that work done. There are a number of things that can be done, diplomatically, that will bring results.

We must remember that all the railroads have been very busy with war work, and it has been an inopportune time in some respects to accomplish results. I have been unable to get the one road to do much work.

Mr. HARDENBURG. Mr. Chairman, we had no difficulty in Macon with the railroads. We did not ask much of them, but what we asked they did. I would suggest, where the railroads are unwilling to undo work they have done which is causing malaria, that you treat the condition as a public nuisance and take proceedings against them. I think you can generally get action in that way.

Mr. PINCUS. Mr. Chairman, at Anniston, we also had varying experiences with the railways in obtaining their cooperation toward the elimination of mosquito breeding in our district. If the railroad corporations have souls, as a previous speaker has stated, I believe there were distinctly three kinds of souls in the Anniston zone.

The one railroad company that had no tracks laid in Anniston, merely possessing a right of way through this section and whose general offices were over 500 miles distant, gave the most generous and ready response to our call for cooperation. When notified by letter that malaria-producing conditions existed upon their right of way, an engineer was on the ground to look over the proposition ere we had time to consider. The situation was surveyed together,

methods for correcting the conditions arrived at which were mutually satisfactory, and before the railroad engineer departed arrangements for performing the necessary drainage work had been made with a local grading company. In a very short time in all, the mosquito nuisance which had existed in the very heart of the town, but a block from the city hall and county courthouse, had been remedied with good psychological value for the remainder of the work.

Another railway system whose district offices were but three squares distance from our offices was decidedly dilatory in eliminating their mosquito nuisances. Several communications were sent out and repeated conferences held, but for variously assigned reasons such as labor shortage, needed authorizations, etc., the work continued to be delayed. Finally, almost in midsummer, the railroad put on a special drainage crew, dug the necessary ditches, made several large fills and installed three 24-inch cast-iron pipe culverts.

The third railroad was the largest of the railway systems encountered, and at the same time the hardest to deal with. Repeated notices with detailed sketches showing the conditions were sent to the district office, but did not even elicit a reply. The matter was carried through the city mayor to the local legal representatives of the railroad company, who forwarded the report of the nuisances to the railroad with their recommendations for immediate correction. After four or five months' delay, a complaint was entered in the local recorder's court and summons issued to the freight agent of the railroad. Within four days the chief maintenance of way officials with a crew of bridge builders were on the ground to investigate exactly what was desired. A week later there had been 50 feet of 36-inch cast-iron pipe culverts installed, extensive ditching, and over 10 carloads of filling performed.

Though the method of persuasion and cooperation is considered always preferable and was first attempted in each instance at Anniston, it is at times very helpful to make use of what legal means are available in prosecuting the malaria control work.

Mr. Harrub. Mr. Chairman, I would suggest that in taking up these matters with the railroad managers that whenever possible a sketch showing exactly what is wanted, together with an estimate of the cost, be furnished them. More prompt action will ordinarily be secured in that way.

Mr. Shaw. Mr. Chairman, I have had some experience with railroads and can say that generally they wish to know the cost of the work requested of them. One railroad which terminates in Lake Charles had accomplished considerable work which was requested by the local health officer before I took charge of the malaria operations. But finding other work to be done, I took the matter up with

their local representatives, who advised me that he had been instructed to do whatever we requested, but at that time was greatly in need of labor for the usual track work. This matter was referred to the superintendent of the company, who immediately instructed me to do the work with our forces and the company would bear the cost. In this case they did not question the extent of the work. The weekly pay rolls were sent to their office and received reasonably prompt attention.

In the case of another railroad entering Lake Charles it was a most difficult matter to secure cooperation. Following a tour of inspection with the local authorities, an article appeared in the newspaper stating that the majority of the initial work had been accomplished excepting that on the property of this company. The following day the superintendent and local representative conferred with the local health officer and myself, assuring us of their cooperation in the future.

During my experience in the vicinity of cantonments, railroad companies have generally been willing to cooperate, but it is difficult to secure prompt action.

Dr. Carter. I would like to answer Dr. Williams's question in one particular—as to what extent the property owner is responsible for a nuisance on his property. The laws in the various States differ on this point. In Virginia it is equivalent to changing the constitution to have a nuisance abated that existed prior to the present occupant's ownership. On the other hand, a nuisance that an owner himself has created the law will not let stand for a minute. Where natural malarial conditions existed on a railroad property, it may be that you have no remedy in law, but where the railroad itself has made the nuisance it must remedy it. It may be, however, that if the nuisance has long existed, it will be difficult to get redress. In the South and Southwest the railroads greatly increased the malaria which existed under natural conditions. In Virginia, South Carolina, and I think Alabama, water can not be impounded without a permit from the State health officer. Exactly the same thing should be required from all railroads in malarious sections. No railroad should be allowed to consider its roadbed complete until it has been surveyed by the State health officer to see if it had done what was reasonable to prevent the spread of malaria. Wherever your problem is a malarious condition caused by the railroad itself, such a condition the railroad can be made to correct unless barred by long existence. Generally, in my experience, they are very willing to correct such self-made conditions without compulsion—that is, all save one.

Mr. Van Hovenberg. Mr. Chairman, first of all, in justice to railway engineers, I want to say that my observations have been that

they are men of merit and ability, and of an order well above the average plane of engineers. With respect to cooperation between railway and local governments, my experience has been that there is alway a willingness to cooperate, once the matter in question is presented in concise business form to the responsible official. My advice to those who must solicit aid from railways is that they go direct to the highest railway official they can find and talk business. These officials are men of clear insight and of prompt judgment. If you don't get what you want, my advice is to wire for Dr. Carter promptly.

Railway hospitals are generally supported by hospital association dues, deducted from the wages or salaries of employees, supplemented by funds supplied by the railroad. Members of the hospital association are entitled to medical and surgical relief at the hospital free of charge. Some hospitals have dental clinics and venereal-disease wards for treatment of employees. Some railways furnish medical and surgical treatment to employees through contract surgeons in the cities along the line.

In my study of railway hospitals during the past few months, I have noticed a very large reduction in the general admission rate, sometimes amounting to 50 per cent. Searching for a reason, it is asserted that prohibition and increased wages have caused this decline, together with a general reduction in the prevalence of malaria.

A word more with respect to cooperation of railroads in malaria control and general sanitation. My opinion is that it is high time the railroads demanded an exchange of cooperation. They should demand that the cities through which they operate have clean eating houses, clean hotels and rooming houses, safe ice and water supplies, sewers available for connection with plumbing in stations and offices, adequate police protection for railway property against vandalism, etc. Railroad employees, such as trainmen, traveling auditors, and engineers, will welcome clean restaurants and screened hotels, and so will the traveling public. Let us have a new kind of cooperation between the railroads and the cities, a kind of cooperation that benefits both parties.

Dr. Carter. We will now proceed with the next subject on our program—"Tide gates." Mr. Fuchs will please open the subject.

TIDE GATES.

A. W. Fuchs, Assistant Sanitary Engineer.

In the vicinity of Wilmington, N. C., there are thousands of acres of abandoned rice fields. Rice cultivation was given up 25 years ago because of competition elsewhere by machinery, which could not be used here.

The surface of the rice fields and wooded swamps adjoining them are 2.5 to 3 feet above mean low tide. The tidal variation at Wilmington averages 2.7 feet. Hence the average high tide floods most of the fields, and full moon and storm tides cover them completely. These abondoned rice fields are covered with very rank growths of cat-tail, saw grass, sour grass, and lily pads. The swamps grow mostly sypress and gum. The top soil is clay, but contains so much decayed vegetation that it is porous. Due to continuous flooding the soil is boggy.

In the numerous ponding areas and in the old ditches there is considerable breeding, about half Anopheles and half non-Anopheles. Ponds and old ditches are filled with rank vegetation, thus preventing fish control, although top minnows are numerous. Summer anophelines are *A. quadrimaculatus;* fall anophelines mostly *A. crucians.*

A combination of methods was adopted in the control of abandoned rice fields and wooded swamps. Ditches drain the fields and carry the water to the outlet at the tide gates. Dikes were built to keep out high tides. Tide gates were installed to allow the discharge of the water on the falling tide, but which closed on the rising tide.

Branch ditches to ponding areas were not found advisable. It proved better to have a main ditch, preferably just inside and parallel to the dike, with parallel laterals spaced 200 to 400 feet apart, connected at upper ends by a seepage ditch following the foot of the hill, as shown in the above diagram. In rice fields 200 feet spacing of laterals was used, but probably 300 feet would have been satisfactory. In swamps 400 feet spacing of laterals was used and proved sufficient. The main ditch was dug about 2 feet wide, laterals about 1 foot wide, with vertical sides, and about 2½ feet deep. Ditching was done with the lightning hay knife and the potato rake, and in loblolly mud with mud scoops. Where the ground was very soft saplings were used to support the sides of the ditch. The average cost

of ditching in rice fields was 12 cents per linear foot; in swamp, 26 cents, the labor rate being 35 cents per hour. Ditching proved difficult and costly on account of the tides. Hence it is preferable to build dikes and tide gates before ditching.

In the construction of the dikes in most cases the old line of rice field dike, though mostly washed away, was followed, cleared, and raised. Where absolutely new dike was built it was located 30 or 40 feet from the river, thus leaving a narrow strip of marsh to protect the dike from wave action. The dike was built up to an elevation 6 inches above average high tide with 6 inches extra for settlement. Several times a year a combination of full moon and storm tides will overflow this dike, but so far very little damage has been done. The average dike built was about 2 feet high, with a top width of 2 feet, and a bottom width of 4 feet. A core ditch was first excavated about 1 foot wide and 1 foot deep or more along the center line of the proposed dike for bonding. Where the main ditch in a rice field parallels the dike the excavated material from the ditch can be used for building the dike, thus reducing costs. The dike should be located not less than 8 or 10 feet away from ditch to prevent caving of the ditch. When a leak develops in the dike the core ditch must be deepened until it cuts off all holes. Over 1.5 miles of dikes were built here at an average cost of 35 cents per linear foot.

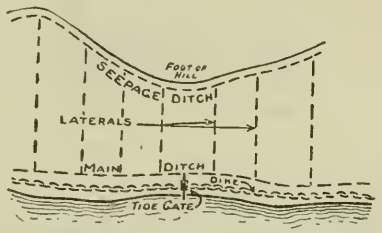

FIG. 3.—Diagram showing methods of control for abandoned rice fields.

The sluice box (see sketch) is merely a wooden-box culvert made of 2-inch plank and well braced. The length is determined by the height of the fill and the natural slope of the filling material. The upstream end is open, but the downstream end is equipped with a hinged shutter. The cross section is determined, as for culverts, by the drainage area, rainfall, and run-off. Where the required size becomes too bulky to handle (the box is built on the surface and lowered into the excavation) it is best to use two or more boxes side by side. The shutter is made of 2 or 3 inch plank, braced with transverse planks. To insure the tight closing of the shutter, the shutter end of the box is given a slight slope; 1 inch per foot has proved satisfactory here. To prevent the floating of the shutter on the rising tide it is weighted; a piece of old iron is usually used here weighing 10 to 20 pounds. In order to prevent floating débris from interfering with closing of shutter, it is advisable to completely submerge the box so that the top is at least a foot below low water. A submerged box will not rot as soon as one subject to periodic wet-

ting and drying. Even with the box submerged we have occasionally had trouble from sunken logs, and are contemplating the use of screens made of heavy fence wire faced with chicken wire mesh near both ends of the box.

Many kinds of hinges have been tried (see sketches): (1) The common strap ringe does not permit enough freedom of movement

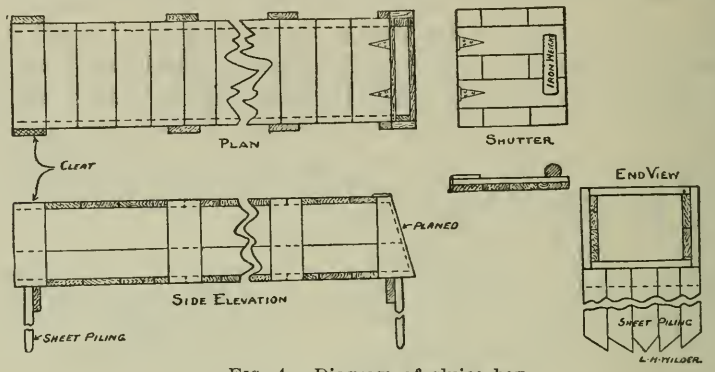

FIG. 4.—Diagram of sluice box.

of the shutter so it can automatically adjust itself against the end of the box. Also it does not permit the easy removal of the shutter for repairs. (2) The rice field timber hinge in which the shutter is attached to two vertical planks which swing from a bracket supported by posts. This type works well and is easily removed, but being above water permits of tampering and rots quickly. (3) Two eyebolts welded together, one bolted to the box, the other to the shutter. (4) Screw hooks in the shutter working on eyebolts on the box. This works fairly well. (5) Screw eyes in the shutter works on a bolt supported by a strap attached to the box. By knocking out the cotter pin the bolt can be pulled out and the shutter removed

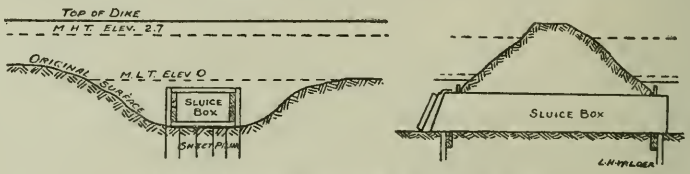

FIG. 5.—Diagram showing location of sluice.

Excavation is make for the sluice box by constructing a rude cofferdam, using dirt for the ends, the water being baled or pumped out. The box may be set directly on the dirt bottom if it is smooth and hard, or on piling driven under the ends of the box. Leakage through the shutter is usually negligible, but if it starts around or under the box it is difficult to stop.

Sluice boxes are the cheapest and most satisfactory type of gate where the stream is not too large. Three sluice box gates have been built here: (1) A 3 by 4 by 16 foot box placed several feet under water cost $202; (2) a box 2 by 3 by 16 foot just below low water cost $33; (3) a 2 by 3 by 20 foot box just below low water cost $105. The labor rate was 35 cents per hour. Costs include both labor and materials.

The type consisting of a single line of sheet piling appealed to me on account of its simplicity and low cost, no dirt fill being required.

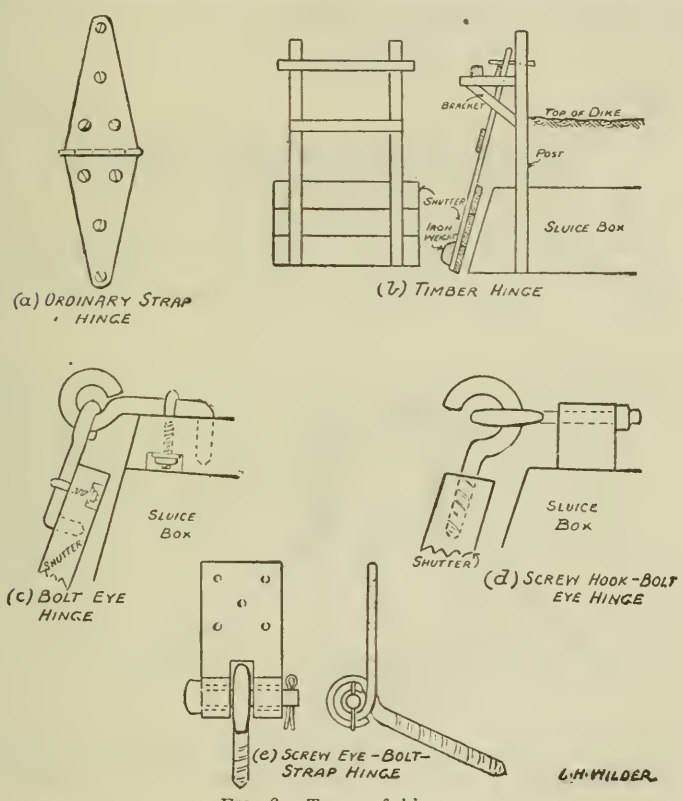

FIG. 6.—Types of hinges.

But owing to recurring pressure at high tide it was gradually loosened, causing leaks. This type might be made satisfactory for small streams having a firm subsoil, by bracing heavily with large piles. A gate of this type tried here proved unsatisfactory. A gate of the third type is now in course of construction on Green Mill Creek. It consists essentially of an earth dam the upper 7 feet of which are protected by 2 lines of 2-inch horizontal planking 11 feet apart supported by vertical piles 8 feet apart, the latter tied together transversely by steel rods above and below the planking. Below the

planking the fill assumes the natural slope of the filling material. At the elevation of greatest weakness, i. e., at the bottom of the planking, a row of sheet piling along the longitudinal center line of the dam is used to prevent leaks. Beyond each end of the dam are 2 sluice boxes 2 by 3 by 16 feet long, giving a cross-section area of 3 square feet per square mile of drainage area. A spillway will be made over the middle of the dam. This type was adopted here because the bottom of the creek is filled with old timbers and stumps, precluding the use of sheet-piling walls; also because it is expected this type will be considerably cheaper.

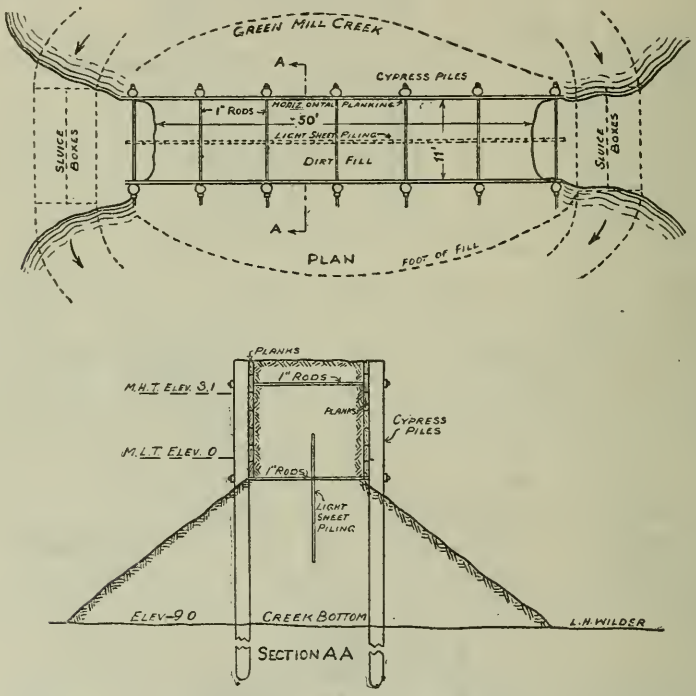

FIG. 7.—1st, Tide gate on Green Mill Creek. 2d, Earth dam with plank protection between elevations of tidal variation—sluices on ends.

A dam consisting of an earth fill confined between two rows of sheet piling was used on Greenfield Creek. The sheet piling was driven at least 10 feet in the mud. A sluice box resting on short piling pierced the middle of the dam. Two small shutters were used instead of one large one to minimize warping. Horizontal stringers were used to keep the sheet piling in line. Transverse iron rods tie the two lines of sheet piling together near the top. The lumber was not creosoted, because we do not have the teredo. This dam and gate cost about $1,700—$400 for materials and $1,300 for labor at 35 cents per hour. A leak has developed under the box, which we

have not yet been able to shut off completely. In spite of this, however, at high tide there is over 2 feet difference in water level between outside and inside.

The amount of protection required by the dam depends on such local conditions as range of tide, character of soil, amount of ice formation, width and depth of stream, proximity to wave action, etc.

By the use of tide gates the water in the ditches and streams is maintained practically at the elevation of low tide. During rains there is an accumulation of several inches of water, but this is discharged at the next low tide. When the water in ditches becomes stagnant the gate can be opened and fresh water admitted, bringing top minnows with it.

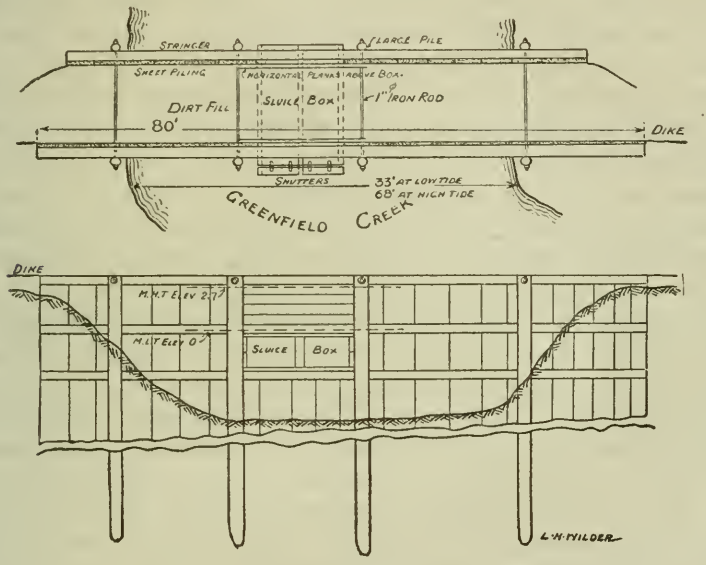

FIG. 8.—Tide gate on Greenfield Creek.

DISCUSSION.

Dr. CARTER. I will ask Dr. Carroll to tell us something about tide gates.

Dr. CARROLL. Mr. Chairman, I do not know much about tide gates personally. But besides those described this afternoon there are two other types of gates used in New Jersey. I shall speak briefly of one and leave the other type to Capt. Gies. The one which I shall describe is used in the southern part of the State.

At a number of places in south Jersey there are soft marshes separated from the bay by sandy beaches. The outlets from these marshes are channels through shifting sands. If you put in gates like those described this afternoon they quickly fill up. At all

such places — I hope some one will suggest a better — we plan to run terra-cotta pipe through the beach, or sand bar, and connect with iron pipe running out under water so as to deliver the discharge from the marsh a foot or two below mean low tide. On the inside of the beach the pipe line connects with a well with planked sides. On the marsh side of the well is hung a tide gate. Leading back from the well into the marsh, and connecting with the ditching system of the latter, is a large ditch with planked sides. We have had one of these gates in operation for three years and in every way it has worked well. The only difficulty we have had with this particular gate is that it is in rather an exposed place in winter. During heavy storms, accompanied by drifting ice, it is rather difficult to keep the iron pipe in place. It is necessary to use heavy piling and cross timbers. We first used timber that was too light. We are now using heavier timber, and it holds.

As I said before, I hope some one will suggest a better method of dealing with shifting sand spits. The pipe lines just described are rather expensive.

There are quite a number of details connected with the gates we have been hearing about this afternoon in which our practice differs from Mr. Fuchs's. Capt. Gies will now tell you about these details and describe the other type of gate referred to.

Capt. Gies. Mr. Chairman, I wish to describe a wooden gate in use in New Jersey and elsewhere which instead of being a wooden box with the gate hung on the end, had been constructed with the top of the box left off. It is merely a long straight-sided wooden trough with the gate hung on the end, had been constructed with the top off at right angles to the trough. It has a screen on either side of the gate, at the end of the flume, to keep out floatage. This type of gate has several advantages. It is easier to repair than a closed box flume. Another advantage is that of being able to see clearly any obstructions that get in. You can then reach down and pull out débris of any sort that may get in.

We do not put our gates quite as deep as Mr. Fuchs has described. Our gates are usually set with the bottom of the flume 1 foot below mean low tide. Our creeks are usually not deep enough to put the gates lower. The point to observe in the determination of the elevation of the gates with reference to tide level is the character of the outlet. If the gates are placed directly on the bank of a deep river or bay, where the bottom on the outlet side falls away sharply below the grade of the gate to an elevation considerably below mean low tide, there is little danger of mud collecting in the flume no matter how deep it is placed. If, however, the gate is placed in a ditch or creek where the elevation of the bottom is practically the same on

the inlet and outlet side of the gate, it will be impractical to place the gate below the level of the bottom of the ditch on either side for it will simply fill up with mud to the level of the bottom of the ditch. Most of our New Jersey gates can be placed only in shallow tidal streams whose bottoms average only a foot below mean low tide. It is practical to put the gates entirely below mean low tide only when the outlet is deep enough to prevent forcing back an accumulation of mud into the flume.

Then we had another problem in connection with our tide gates. When the gates were closed, the fish could not get into the marsh, and where the fish supply got low on the diked and sluice-gated meadow there was more or less mosquito breeding. This was particularly the case where sewage was discharged through the meadows, for a little touch of pollution is very attractive to some kinds of mosquito breeding, particularly *Culex pipiens*, the house mosquito. This attractiveness is probably due to the richer organic material in polluted water, providing more food for the larvæ.

In order to overcome this breeding in the ditches inside the diked and tide-gated meadow we have left our gates raised for about two weeks each month during the summer, during the period of the lowest tides each month. This allows the fish supply to be kept up by the free entrance of the fish into the ditches, with the consequent destruction of the mosquito larvæ. Moreover, by raising the gates on one side of the marsh and allowing water to enter while keeping the gates on the other side of the meadow closed, except for discharge of water, it is possible to get circulation of the water through the ditches across the marsh and sweep out breeding by this mechanical action. The gates are all closed during periods of monthly high tides or storm, so the unusually high tide water will not back up over the meadows and flood the thousands of surface depressions on the marsh and thus start mosquito breeding on a large scale.

There is one other point that has not been touched on, that is the matter of meadow shrinkage if the gates remain permanently closed. Most salt marshes are composed of a top layer chiefly of decayed vegetation or peat on a foundation of blue clay, mud, sand, etc. The elevation of the meadow surface is kept up to a point slightly above mean high tide by the continuing growth and decay of the salt grasses, sedges, rushes, etc. This class of vegetation needs plenty of salt water to attain maximum growth and hence if the tide gates are kept continually closed and the salt water excluded from the marsh, the growth of the surface vegetation stops and the spongy top layer of peat dries out and begins to pack down hard and the marsh settles down lower and lower. In parts of Hudson County, N. J., this shrinkage has amounted to several feet.

Finally, a point is reached where the elevation of the meadow has become so low that it can no longer be drained by ditches or tide gates and it is necessary to install pumps which increases the cost of mosquito control. In parts of Hudson County, where the meadow elevation is very near mean sea level or lower, a very excellent system of pumping has been worked out by Mr. Delaney, and similar systems have been installed by the Pennsylvania Department of Health on low-lying marshes near Philadelphia. These pumps can be electrically driven and are automatic in operation, being regulated as to starting and stopping by a simple float which is raised or lowered by the water on the meadow, and starts or stops the pump accordingly.

I think that all meadows inclosed by a dike and tide gates will shrink to a greater or less extent, depending on the thickness and capacity for shrinkage of the top layer of decayed vegetation that composes the meadow, unless the salinity of the marsh is kept up by keeping the gates open sufficiently so that the vegetation will continue to grow. We are keeping the tide gates open in our own district, not only for about two weeks out of every month during the summer, but during the entire nonmosquito breeding season, from November until March. We hope in this way to keep up our marsh elevation by continuing our vegetation growth, so that we will not be forced to the extra expense of pumping.

Dr. Carter. Gentlemen, on account of the late hour, we will take a recess until 8 o'clock this evening, when we will meet at the marine hospital for further discussion of this subject of tide gates. I now declare the meeting adjourned until 8 o'clock this evening.

Evening Session, February 17, 1919.

The conference reconvened at the marine hospital at 8 o'clock, Asst. Surg. Gen. Carter presiding.

Dr. Carter. We will now resume our discussion of tide gates. Are there any questions?

Mr. Frank. Mr. Chairman, I should like to secure information as to the limiting conditions under which tide gates are necessary. It is obvious, of course, that where it is the intention to reclaim areas for agricultural purposes tide gates will be necessary, even though they might not be necessary for mosquito control only.

Confining the question, then, to the matter of mosquita control only, under what conditions is a tide gate necessary? What must be the elevation of the surface of the marsh above low water to render tide gates unnecessary?

Mr. Delaney. Mr. Chairman, replying to the question just asked, permit me to say that in 1867 the Pike estate purchased about 5,000

acres of meadow land in Hudson County, N. J., for speculative purposes. At that time the meadows on the west side of the Hackensack River, comprising such purchase, were on a level with high tide in the Hackensack River. They built a dike about 7½ miles long from southern Hudson County to the northern end of the county, running parallel with the Hackensack River. In the center of this dike they sunk iron slabs half-inch thick, to prevent burrowing animals destroying the dikes. They did this drainage for reclamation purposes; previous to that time, corn had grown on these meadows to a height of from 8 to 10 feet, but bore no grain. Instead of reclaiming this territory, it immediately began to depress, and it has since been depressing until it is now almost down to low-tide level. Seven sluice gates were installed along this dike which we find working almost perfectly to-day. These gates are very low, always submerged, and are free from destruction by floating ice. This dike and sluice gates were intended for reclamation purposes, but instead of reclaiming, they rendered this territory almost beyond reclamation—certainly useless for agricultural purposes.

On the east side of the Hackensack River, which was once of the same elevation as the west side, we still find sluice gates unnecessary. The meadows have not sunk and drainage by gravity is perfect. Such conditions suggest the question, "When are sluice gates necessary?" Our conditions in the east are so vastly different from the conditions found here that I do not think a further discussion of the former would interest you. I should say, however, that tide gates are necessary on the abandoned rice fields which we inspected this morning along the river fronts, because you have not the long period of drainage between tides, because your tide only rises, as I understand, about 2 feet. If you had a drainage period between tides, as we have, of from six to eight hours, I do not think that tide gates would be necessary on the narrow fields in question. If you had such a drainage period, I am inclined to think that with deep, straight ditches you would be able to keep these fields free from breeding, because even though they were occasionally flooded, the water would be drained from the surface of the meadows and returned to the river through properly made ditches between tides.

We have in our county a territory covering about 2,500 acres of swamp land, the elevation of which is only about 4 inches above low tide in the Passaic River. Gravity drainage here is out of the question, and we are compelled to use electric pumps. We have 3 such pumps in operation, 1 of which throws 2,800 gallons per minute. These pumps require very large supply ditches. They work well and have proved a complete success.

Dr. Carroll. Mr. Chairman, I do not think the question that was asked, i. e., when dikes and tide gates are necessary, has been an-

swered as fully as it might be. It seems to me you can usually tell by looking at a piece of marsh whether you can get the water out. If not, there will be no doubt about the matter after you have cut your ditches. Where there is a narrow or an open marsh and a tidal fall of three or four feet, dikes and tide gates are certainly not needed. If the fall of the tide is sufficient to draw all the water out of the ditches at low tide there is, of course, no need for diking or tide gating. There are many tidal marshes, however, which are almost entirely inclosed by upland or by the artificial embankments of roads and railroads. These inclosed, or semiinclosed, marshes are apt to have but one outlet. The latter may be through shifting sand or soft mud or other material that makes it difficult or too expensive to keep the channel clear. Under such conditions the marsh may be flooded by every storm or extra high tide and stagnant water remain on it for weeks. The only remedy here is tide gating. Again, it may happen that on a broad open marsh, especially if the range of tides is small, there are spots or "pockets" back near the upland too low to drain by ditching. In such a case it may be necessary to build dikes and tide gates in order that the water in the ditches may be kept constantly at a low level, in order to draw the water from these pockets.

Mr. Gorman. Mr. Chairman, during our inspection trip this morning we were shown a tide gate which failed to close with the rise in the tide, due to the débris collected in the gate opening. This almost entirely defeated the purpose for which the gate was installed. In view of the fact that a great deal of water-logged débris may be expected to be moved toward these gates with the rise and fall of the tides, would it not be economy to install vertical racks on each side of these gates to prevent this débris from interfering with the action of the gate?

Mr. Van Hovenberg. Mr. Chairman, I would like to know if any of the gentlemen have had any experience with the Calco gates. I also would like to ask Dr. Carroll whether it would be possible to control Anopheles breeding in the marsh we saw to-day by adequate ditching without the use of tide gate?

Dr. Carroll. I should say not. However, I prefer not to have too much to say. I am here to listen and not to talk, to learn and not to instruct. I would like that question answered by some of the others who have had more experience than I have had with tide gates and dikes.

Mr. Le Prince. Mr. Chairman, I would like to ask Dr. Carroll a question. The one-half dozen gates I saw in New Jersey were equipped with screens for keeping the débris out. I would like to know if that is a customary practice in New Jersey.

Dr. Carroll. Mr. Chairman, I would not say it was customary. It is often done, and I think it can be done very cheaply at the inner end of a sluice box, but, of course, on the outer end it is rather expensive. Perhaps Capt. Gies can give you more information on this subject.

Capt. Gies. Mr. Chairman, replying to Mr. Le Prince, I think it is customary in New Jersey to put a coarse rack or screen at either end of the tide gate made of 2 by 4-inch lumber, the pieces spaced parallel to each other about 4 inches apart. That keeps out heavy floatage and débris. There is a good deal of fine stuff that gets through that is apt to lodge in the gates, so that it is very advisable to have a man look them over every three or four days. In order to have your gates effective, you must have them inspected frequently by some one detailed to that duty.

The point was raised as to the necessity of dikes and tide gates on low-lying marshes. On the high-lying marshes there is usually sufficient fall to quickly drain off all surface water by systems of ordinary open ditching. On the lower lying marshes, however, particularly those with inadequate outlets, although the open ditching system alone may be sufficient for mosquito control for ordinary weather, it is entirely insufficient during abnormal weather. Frequently a period of high tides, heavy rains, and severe storms may occur: the tidewater outside the meadow may remain backed up at practically high-water level for 10 days, and a meadow unprotected by dikes and tide gates will be flooded and an enormous brood of mosquitoes may develop before the water can run off. A season's work may thus be nullified by the escape of this one brood that may hang on and annoy people for weeks.

The system of dikes and tide gates may thus be considered as insurance against emergencies, not needed in good weather at all but ready at times of special danger to practically absolutely check the great infestation of mosquitoes which would otherwise occur from a salt marsh.

In regard to protecting dikes against muskrats, brown rats, and other rodents which may burrow through and undermine the dikes, we have used ordinary chicken wire vertically in the middle of the core of the dike carried down 2 to 4 feet below the meadow surface, and prevented these animals getting through. Trapping or poison baits could also be used.

Mr. Fisher. Mr. Chairman, the question has been asked as to the efficiency of Calco gates. Two of these gates were installed by the quartermaster at Norfolk in the area outside of the Army base and they work satisfactorily. They are said to be sensitive to a difference of head of three-fourths of an inch. These are 30-inch gates

and are placed with their tops below low water. It was necessary in placing the gates to put in a concrete core wall, which made the job expensive. The gates cost $45 at the factory, and the total cost of the installation from two thousand to twenty-four hundred dollars.

With regard to the necessity of using tide gates, my opinion is that when the marshes are narrow, so that the ditches are short and the water can drain out at low tide, no tide gates are necessary.

Mr. Fuchs. Mr. Chairman, I think I tried to impress upon the gentlemen this morning when inspecting the rice fields, and in my paper this afternoon, some of the reasons why we submerged our sluice boxes below low water. This method has its advantages and disadvantages. It is more costly than placing them higher. The main reason for submerging them was because floating logs and other débris can not enter the sluice boxes, and a good deal of trouble from this source is eliminated. Of course, once in a while a log will get water-logged and sink, in which case it may get into the sluice box and prevent free action of the shutter. Another reason why we put the sluice box so it was submerged was because the timber will last much longer under water than when subject to alternate wetting and drying.

We have considered the question of screens in our work here. I do not think it would be difficult to put them in. I am contemplating doing that if it shall become necessary. My idea was to put down two posts on the edges of the ditch and strong heavy fence wire faced with chicken wire across from high-water mark down to the very bottom. The heavy fence wire would be a good protection against heavy obstructions and the light chicken wire will keep out most of the floating débris. I think we may have to do this before this work is over.

With regard to the cleaning of submerged sluices if that should ever become necessary, I would like to point out that there is a swift current at high tide when the gate is open, and while we have had no trouble with matter collecting inside the box, I think the mere opening of the gate would sweep the sluices clean.

As regards the stagnation of water in ditches that Capt. Gies spoke of, the system of circulation used in New Jersey to counteract it is undoubtedly a splendid device. I also am planning, when the water becomes stagnant and the fish begin to disappear, on opening the gates to admit fresh water from the river, bringing with it top minnows, and in that way keep the rice fields in such condition that practically no oiling is necessary.

As to the question of when dikes and tide gates are necessary, I may say that when this work was started there was no intention of building dikes and gates. When it was found that very little progress in ditching could be made because of the high water they had to be

put in. It was with this idea in mind that the bureau was asked to appropriate money for experimental work to find out whether these rice fields could be drained without tide gates and dikes. The ditching will be more expensive under such conditions. How much more, I can not tell. Difficulty in construction will be encountered. About 50 acres of swamp and a similar area of abandoned rice fields will be selected and ditched, using ditches 300 feet apart without tide gates and without dikes. Comparisons of the cost per acre of the work with and without tide gates and dikes is desired.

Another thing to find out is whether ditches alone will be able to carry off the surface water. The rice fields are located at about high-tide elevation. Whether we will be able to drain these fields at low tide by mere ditching is a hard question to answer. If the water will run off between tides the ditching will be successful. The tide gates are sort of a safety factor. When ditches alone are used, if a heavy rain should come the ditches may not carry off the surface water and in such event there would be great danger of breeding taking place.

If we had had money enough on this work we would probably have used concrete construction. There is no question as to its superiority. We have put in three simple sluice boxes. One cost $33 complete, one $100 and the third $200. Compare that with the cost of concrete construction or steel sheet piling. You can see that the latter two methods would be out of the question with limited funds. It would be very interesting to find out the cost of concrete construction for tidal gates. I would like to get hold of that cost. But even if we had the money available to build concrete gates, I have serious doubts as to whether under such conditions as we have here, where the mud is so soft that we sink piling 25 feet deep in the mud before striking a solid foundation, it would be possible to use such construction without the use of expensive, heavy sheet piling.

(The meeting was adjourned at the close of the discussion on tide gates at 9.30 p. m.)

Morning Session, February 18, 1919.

Dr. Carter. The first subject for our consideration this morning is subaqueous saws. Mr. Gorman is asked to open the subject.

SUBAQUEOUS SAWS.

A. E. Gorman, Assistant Sanitary Engineer.

Subaqueous saws were successfully used in cutting aquatic vegetation from Crawfish Lake, at Chickamauga, Ga., last summer. Although called a lake, this body of water is really a part of Chickamauga Creek, the current being quite noticeable. At its widest point the lake is about 350 feet across.

The familiar "bottle washer" aquatic plant (pond weed) and long-bladed water grasses fairly covered the bed of the lake. The tips of these plants lay on the surface of the water and caused mats of green slime to gather. Investigations showed that this "floatage" offered ideal breeding places for Anopheles.

At the extreme upper end of the lake was a shallow cove, in which were several springs. Water cress fairly covered the water surface and "dips" showed marked breeding of Anopheles there also. In such shallow water, laborers were able to pull out all the water cress with drags, by wading. In this manner 15.6 square rods of water surface was cleared at a cost of 80 cents per square rod.

But the clearing of the rest of the lake offered an entirely different problem, and it was realized that subaqueous sawing was the best solution. A double-edged saw for subaqueous sawing is manufactured by Aershot Bros., which sells at about 30 cents per foot, but owing to war conditions an immediate delivery would not have been assured. However in discussing this problem with representatives of the mill, through whose property the creek ran, it was learned that they had used a subaqueous saw occasionally to remove aquatic growths from the lake near the town intake for water. The saw used by them was made from "licker-in" wire used at the mill and in spite of its poor quality of steel, it was decided to try this wire in making a long saw for work on the lake, as it was readily obtainable and cheap.

"Licker-in" wire is used in a combing process in cotton mills and can be purchased from any of the mill-supply houses at about 30 cents a pound, which averages $2\frac{1}{2}$ cents per foot. This wire is similar to a single-edge saw and is $\frac{3}{16}$ inch wide and $\frac{1}{16}$ inch thick at the hilt. The teeth are right triangles, tapered to sharp points, and have a flat cutting edge. They are $\frac{1}{8}$ inch deep and $\frac{1}{4}$ inch on centers. The steel is not well tempered, and in short lengths the

wire will break if bent abruptly, but in long lengths, such as those used in our work, no abrupt bending was necessary.

By tying the hilts of two "licker-in" wires back to back at intervals of 8 or 10 inches, with cutting edges in opposite directions, a double-edged saw was made, capable of cutting in either direction of a sawing motion. In order to weight the saw and still allow it to take the contour of the lake bed, cast-iron tubes, 4 inches long were slipped over the saw and leaded in place at intervals of 4 feet. Two 100-foot saws and one 50-foot saw were used in this work, long ropes being tied to each end.

The method of using the saw was as follows: Beginning at the downstream end, the saw was dropped to the bottom of the lake in the middle third, the ropes stretching to either shore. Usually five men were employed in the work, two operators on each shore and a man to observe the effect of the work and direct the shore men. Whenever the saw became entangled in roots or stumps in the bottom of the pond, the party in the boat could disengage it by using a long hook. The shore men worked in pairs about 10 feet back from the water edge, each holding one end of a 1-inch water pipe 4 feet long to which the rope from the saw was tied. In narrow places, when the short saw was used, but one operator on each shore was employed. Frequent rests were allowed the operators at first, for the sawing motion was very tiresome until they became accustomed to it.

Sawing was done, of course, against the current, the growths rising to the surface as cut, and floating downstream. By purposely leaving untouched a belt of this aquatic growth across the lake, at a narrow place downstream, the "floatage" was obstructed and collected in little islands that could then be conveniently dragged to shore.

At the wide parts of the lake, after the middle section had been cleared of vegetation, cutting on one side was begun. This was accomplished by lengthening the rope on the opposite side of the lake and shortening it on the side on which the work was to be done. In cutting the shore sections, zigzag courses with the saw were taken to work effectively around points and in coves. At times the operators would wade into the water, and in sawing growths in big coves the operators at both ends of the saw would be on the same bank of the lake.

Often the sawing in difficult places near the shore was supplemented by men wading into the water and pulling the growths out by hand drags.

Stumps and rocks were encountered frequently and at such times the boatman would lift the saw over such obstructions. Occasionally these obstructions would break the saw, when a reserve saw had to be used. The boatman could very easily detect when the saw became

dull from the looks of the plants as they came to the surface. Instead of the plant being cut clean as a sharp saw would do, it would be torn and mangled.

The labor cost of sawing 16 acres, surface area of vegetation from this lake, as described above, was $77.50 or $4.85 per acre and $0.03 per square rod, labor 30 cents per hour. This was approximately one twenty-seventh as costly as removing water cress in same lake by hand drags.

The use of this improvised saw in an emergency has demonstrated the possibilities of the use of "licker-in" wire as a substitute for the more costly subaqueous saws now on the market.

H. H. Wagenhals, Sanitary Engineer.

Mr. Chairman, I do not believe that I can add much on this question of subaqueous saws. Mr. Gorman has done more work with them than I have. I received my saw from Wisconsin at the end of the season, after many weeks delay, too late to use on the work for which I had ordered it.

This saw, known as the Ziemsen subaqueous saw, is made of tough, pliable steel to prevent breakage. Of course, breakage does occur, but repairs are easily made. Then two ends at the break are overlapped about an inch or inch and a half and bound back and forth with a tough wire. I would like to know about this feature of operation with the "licker-in" wire, as breaks must be frequent, considering the quality of the wire of which these saws are made.

As regards the use of long extension ropes on the ends of a short length of saw to cut, by successive steps, wide areas of vegetation, I would say that I did not have very much success. The rope seemed to be harder to draw than did the saw. The makers claim that the Ziemsen saw can be used in lengths up to 1,500 feet. I feel that it is a feasible device up to 200 to 400 feet, and would recommend the long lengths for wide stretches of vegetation.

Under certain conditions, the use of a saw does not appear feasible. I had one pond with a dense growth of moss on the bottom. This moss wound itself around the saw, clogging the teeth, and necessitating frequent cleaning. This took the entire time of two men in a boat and held up the men on the bank. I do not know how the cost of the job would have compared if done entirely by hand.

I feel that this question of subaqueous sawing is worthy of a good deal more study and experimentation, both as regards the economy of operation and the type of saw. It would appear to me to be better to invest in a relatively inexpensive saw of good material and use it for several seasons than to get a cheap grade which may have to be replaced several times during a single season.

Discussion.

Mr. Hoskins. Mr. Chairman, in our work we used the Aschert Bros. saw, the same spoken of by Mr. Gorman. One point not brought out in the description of the Aschert saw is that the blade is

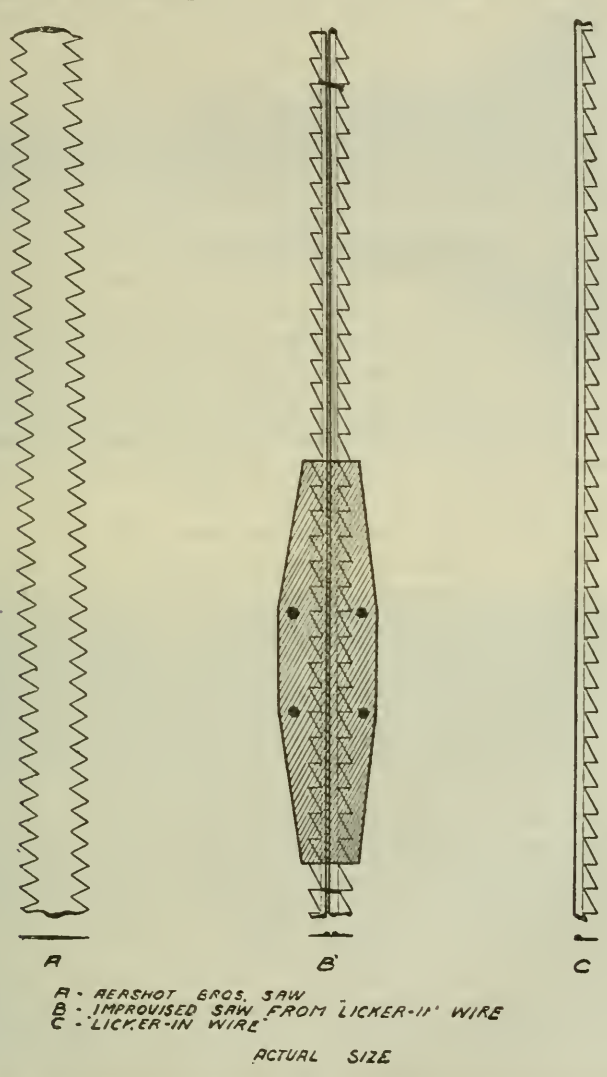

Fig. 9.

twisted in the form of a spiral, which renders its work much more effective in cutting. We had some difficulty in regard to the delivery of that saw. I would like to ask from some of the men who have used saws how long one sawing would suffice. Did you use the saw once a season, or every few weeks? At Macon we started late in the season,

so we were unable to judge the length of time the cutting was effective.

Dr. CARTER. Gentlemen, at Quantico we had perhaps 600 acres with a growth very similar to that at Chickamauga described by Mr. Gorman. It is the so-called wild celery, eel grass—*Vallisvenia spiralis* is the botanical name. I was more fortunate than Mr. Gorman in getting the botanical name of the growth from the Bureau of Plant Industry. There was an enormous amount of the lotus plant, also. There were absolutely miles of it up to the Potomac. In the latter part of August, 1916, and from the 15th of August, 1918, the floatage caused by these plants was producing *Anopheles quadrimaculatus* profusely. It was the heaviest production I have ever seen over so large an area. The dipping had to be done by boat, and we averaged eight larvæ at one dip. But at one dip we counted 52. We decided to get a subaqueous saw. This we used in deep water, in some places the water being over 8 feet deep. The saw was used in lengths of 100 to 150 feet. It will not work in any kind of woody material. It cut water lilies, lotus, and eel grass. It has a very limited applicability, but within its limits I do not know of anything else that will take its place. Dr. Ebert, of the United States Navy, was in charge of this work.

As to how often we must cut I do not know. We did our first cutting at Quantico on August 1. The price of the saw has risen, and, as far as I can judge, from the description of the last one I got for Camp Humphreys cost $175 for 300 feet. The use of this saw is almost a necessity in floatage in deep water along the Potomac, as adjacent to Quantico and Camp Humphreys. I was told that a pond at Druid Hill Park in Baltimore in which the growth—I do not know of which kind—had been cut for two seasons was now free from it.

Mr. GORMAN. Mr. Chairman, Mr. Wagenhals during his discussion showed a weld in a Ziemsen saw, where a break had been made, stating that he doubted if the "licker-in" wire could be so conveniently welded, due to the poor quality of steel in the wire. I believe he is right. The grade of steel in the "licker-in" wire is inferior to that in the Ziemsen saw. However, we did mend breaks in the improvised subaqueous saw made from "licker-in" wire, tying the broken sections together with copper wire.

Mr. Wagenhals recommended that saws longer than 100 feet be used in this work, stating that the manufacturers claim that these subaqueous saws can be used effectively up to lengths of 1,500 feet. From our experience at Chickamauga, Ga., last summer, where the whole bed of the lake was overgrown with aquatic plants, I doubt if a saw of over 100 feet in length could be used to advantage.

FIG. 10.—CRAWFISH LAKE, SHOWING AQUATIC VEGETATION REMOVED ON ONE-HALF THE LAKE.

FIG. 11.—SUBAQUEOUS SAWING AT CRAWFISH LAKE, SHOWING METHOD OF OPERATING SAW AT A WIDE SECTION.

The resistance offered as the saw passes back and forth through the aquatic growths is great. With a 100-foot saw, using two men on each end, the sawing became so laborious that besides allowing frequent rests for the laborers an increase in salary was necessary to compensate for extra labor. I even doubt if with a saw 1,500 feet long a sawing motion could be maintained for any length of time through thickly grown aquatic plants.

Mr. Hoskins brought out the fact that the Ziemsen saw is twisted so that the cutting edges of the saw form helicals the length of the saw. Our experience at Chickamauga demonstrated that by twisting the saw a better cutting action was obtained.

In answer to the question of how the sawing of aquatic plants affects the growing of a new crop, I will say that in Crawfish Lake our subaqueous sawing was done in the middle of July and late in October none of the aquatic plants had reached the water surface again.

Dr. Williams inquired as to the weight of the subaqueous saw made from the "licker-in" wire. The double-edged saw itself weighed approximately 20 pounds per 100 feet, while the weights at 1 pound each spaced 4 feet apart weighed 25 pounds more, making a total weight of 45 pounds for the saw. Of course, in operating the weight of the water-soaked rope on each end of the saw adds considerable.

In answer to Capt. Gies's question as to whether the subaqueous saws used were effective in cutting brushes, our experience along this line showed that the saws were a failure for this work.

In estimating the probable cost of removing aquatic vegetation by means of the subaqueous saw, due consideration should be given to the nature of the shore line of the body of water in which the work is to be done. Sawing in coves and around points is an uncertain element, which must be allowed for in estimation of the cost.

In summarizing, I believe the subaqueous saw has an important place among devices for controlling mosquito breeding areas and will prove to be a time-saving and economical tool in our work in the future. The improvised subaqueous saw made from "licked-in" wire, while undoubtedly inferior in quality to the standard subaqueous saws on the market, has the following advantages which make its use well worth while in emergency cases:

1. Is readily obtainable in cotton-mill districts, which are very often in the heart of the malarial districts.

2. It is only one-fifth as costly as the standard subaqueous saws on the market.

Dr. Carter. The next subject on our program is vertical drainage. Mr. Stromquist will please open the discussion.

VERTICAL DRAINAGE.

W. G. Stromquist, Sanitary Engineer.

In the Muscle Shoals Sanitary District are found a number of isolated drainage areas which have no surface outlet. Fissures in the limestone, underlying the loam and clay which forms the soil of this region, provide outlets in some cases. Vertical drainage, either by means of natural sink holes or by sinking artificial shafts, was a feature of the work in this district.

Pond Creek, having a watershed of about 25 square miles, disappears into two sink holes near Nitrate Plant No. 2. In wet seasons a large area in the lower part of the watershed becomes inundated. Attempts had been made to increase the capacity of the sink holes, and in one a timber frame about 3 feet square and 12 feet deep was found. It had become clogged with drift.

A shaft 10 feet square was sunk to a depth of about 25 feet. The upper part of the excavation was through red clay mixed with rock. Three limestone projections were encountered about 12 feet below the surface. Between these the material removed included clay, rock, black dirt, and drift which had been washed into the hole. A fissure, extending nearly the full width of the shaft and about a foot high, was found under one of the limestone ledges.

The shaft was curbed to the rock by horizontal braces of double 2 by 8 inches spaced 3 feet apart and 2 by 12 inch sheathing. Short corner braces were made of 2 by 12 inches and the shaft was braced across the center both ways by double 2 by 6 inches at each of the horizontal braces. A flume of 2 by 6 inch tongue-and-grooved material was built from one side of the shaft to the end of the ditch, a distance of 14 feet.

The excavation was made by hand, staging being used as necessary. Later the owner of the land loaned us a hay loader; the cable and trolley were set over the shaft and the material hoisted out in a wooden box with a team of mules.

During dry weather it was possible to divert the flow of the stream to the other sink hole, but after a heavy rain the shaft would be flooded. This caused serious interruptions in the work and increased the cost.

Very little work was done on the other sink hole. Drift and dirt which had accumulated over the opening were removed.

The capacity of the sink holes was greatly increased, but not sufficiently to carry the flood flows of the creek. At Nitrate Plant No. 2 a drainage canal was dug to carry the waste water to the river. A lateral extended to Pond Creek will relieve the sink holes so that flooding of the surrounding area can be prevented.

Sheffield Pond, covering more than 40 acres of city lots near the business center of Sheffield, receives the drainage from a large area of the city. A sink hole had formerly provided partial drainage but in an attempt to improve it the timber crib which was being installed collapsed, and the opening had become entirely clogged with several years' accumulation of silt over the timber. Later a shaft was started at the other end of the pond, but the work was suspended after the excavation had been carried about 10 feet. A seam of black soil through the red clay and sticks and other débris embedded in this material indicated that a fissure might be found.

A shaft 7 feet square was started at the same point. At a depth of 10 feet a cavity was found at one side of the shaft, so it was shifted to center over this cavity. The shaft was carried to a depth of 36 feet, extending about 2 feet into a soft limestone. The material excavated was red clay, mixed with rock in the lower part of the shaft.

The shaft was curbed with 2 by 6 inches, double braced at intervals of 3 feet, and 2 by 12 inch sheathing. A flume 14 feet long was built from one side of the shaft to the end of the ditch.

Although no fissure was found the pond was drained in three days after the water was turned into the shaft.

About one month after this work was completed a heavy rain flooded the pond. When the water receded it was found that the shaft had collapsed and that a hole about 20 feet in diameter and 20 feet deep had been formed. This was apparently caused by a cavity being formed around the bottom of the shaft and the upper stratum collapsing.

In repairing the shaft the excavation was carried 5 feet deeper, a total depth of 41 feet. A fissure about 4½ feet high and 18 inches wide was found in a vertical wall of limestone. In front of the fissure was a solid ledge of rock which provided a good foundation for the shaft. Since this work was completed the pond has been drained without difficulty.

Just south of Tuscumbia was a pond which could not be drained without very expensive ditching. Since two other ponds had been drained into it and the owner of the property objected to the additional water, it was decided to try vertical drainage. A shaft 26 feet deep, 5 feet square, was sunk. The excavation was through cherty, gray and blue clay, the proportion of rock increasing with

the depth. No fissure was found, but the work was stopped when water was found. The shaft was timbered in a similar manner as the two previously described, with 2 by 8 inch braces and 2 by 12 inch sheathing. This shaft does not carry away the water as rapidly as the other two, but with intermittent rains will keep the pond dry although its drainage area has been increased.

In the eastern part of Sheffield, near plant No. 2, was a field where Anopheles larvæ were found repeatedly in a large ditch. A sink hole had formerly drained this field but had become filled. The hole was excavated to a depth of about 35 feet, through red clay into sand below a limestone ledge. No sheathing was placed in this shaft. Two smaller sink holes in this vicinity were cleaned to a depth of 15 feet to drain a pond which had no other outlet. A pond in the northeastern corner of Tuscumbia was drained by ditching to a sink hole which required no cleaning.

The cost of the work is tabulated below. The expense was greatly increased, especially in the case of the Pond Creek sink holes and the shaft at Sheffield Pond, by heavy rains interrupting the work and washing material into the shafts. Laborers were paid $3.30 per day, foremen $6.60. The transportation item covers the transportation of men, and partly teaming: incidentals are mainly teaming.

	Man-hours labor.	Cost.					
		Labor.	Foremen.	Transportation.	Incidentals.	Lumber.	Total.
Pond Creek sink holes	1,812	$532.15	$188.50	$115.85	.....	$100.58	$928.08
Sheffield Pond shaft:							
Original cost	2,107	707.85	233.40	.....	$4.00	127.72	1,072.97
Cost of rebuilding	1,920	647.20	196.05	30.25	60.50	71.44	1,032.44
Total	4,027	1,382.05	429.45	30.25	64.50	199.16	2,105.41
Old sink hole in east Sheffield	721	237.00	69.00	.....	.....	.....	306.00
Two small sink holes in east Sheffield	130	42.90	13.20	.....	.....	.....	56.10
Shaft south of Tuscumbia	661	217.80	72.45	.....	.....	[1] 36.00	326.25

[1] In addition, 1,000 feet of lumber was furnished by owner.

Dr. Carter. Mr. Gorman will continue the discussion.

A. E. Gorman, Assistant Sanitary Engineer.

That vertical drainage in limestone districts is an economical and effective method for eliminating large areas of standing water, in connection with antimalaria work, was demonstrated last summer at Chattanooga, Tenn.

The soil in Chattanooga is the familiar impervious red clay, varying in depth form a few inches to 6 or 8 feet, underneath which is

a stratum of limestone. This limestone is often full of open seams and caves. Occasionally, in the low lands, one of these caves comes to the surface, forming a spring or a sink hole.

At two places within the city limits there are great depressions in the topography, serving as the natural drainage point for large areas of the surrounding land. Having no outlets and with impervious clay beds, these places had been stagnant ponds for years.

One of these depressions collects the run-off from most of the National Military Cemetery and is known as Cemetery Pond. It is about 1,800 feet long and 50 feet wide and has a very level bed. For years this pond, which is in the heart of the residential section of the city, was a prolific breeding place for mosquitoes, and in spite of public protest was allowed to exist, being oiled occasionally during the mosquito breeding season. The bed of the pond was several feet below the invert of the city sewer in that district.

Soon after our malaria control campaign had been launched a petition was received from the city commissioners of Chattanooga requesting that efforts be directed toward abating the mosquito nuisance at Cemetery Pond. An investigation revealed the fact that about 5 feet under the clay, which formed the bottom of the pond, was a stratum of limestone. At this time the water surface was about 37,500 square feet. To fill this pond would have been expensive, so it was decided to try vertical drainage.

Beginning at a few feet from the water's edge, on shore, at a shallow part of the pond, a hole was dug to the limestone stratum with a post-hole digger. Then, with a long drill a hole 12 inches deep was made in the limestone and a stick of dynamite inserted, well packed and exploded. The hole was then cleared out, the drill again used, and another stick of dynamite exploded. This was continued for three or four times until drilling had been carried to a depth of four or more feet in the limestone. Water from the pond was then directed into the hole. This same thing was done at two or three other places around the pond, the effect of the dynamite in loosening the soil causing a marked drop in the water level of the pond. As the water drained and the pond became smaller, other holes were dynamited as described above, and after eight holes had been made the pond was dry. By observing the rapidity with which the different holes drained, it was noticed that four of them were especially effective, while others were very slow, showing that in the case of these four, seams in the limestone had been reached.

These four effective drains were dynamited several more times and then at each of them, holes 2 feet in diameter were dug through the clay to the limestone. In these holes, resting on the limestone strata, 12-inch vitrified clay sewer pipes were placed vertically,

being built up to a few inches above the ground. The rest of the hole around the pipe was then filled with coarse stone and cinders.

A main ditch was then dug in the center of the pond its entire length, with occasional laterals. This main ditch and the laterals lead to the four effective drains described above. During the summer months no especially heavy rainfalls were experienced, but in September 6.48 inches of precipitation, the heaviest on record at Chattanooga, was handled by these vertical drains with no difficulty whatever.

The cost of this work, labor at 30 cents per hour, was $173.42. This included 1,500 feet of ditching and the work on the four rejected drains, which were filled in.

The second depression mentioned above formed a pond in Montague Park. In affecting a permanent drain for this pond a peculiar use of vertical drainage was resorted to. This park of several acres of wooded land, although badly needed in the poorer section of the city, could not be used, because of a swamp and this pond which covered about one-third of the land. This condition was caused by the backwater left after flood stages in the river had inundated the lowlands. Here breeding of Anopheles was marked. In investigating this pond a sink hole was found about 500 feet away and by running levels it was found that the water level in this sink hole was approximately 6 inches higher than the river level and fluctuated with the river. This indicated that there was a subterranean passage or seam through the limestone to the river, which was about a mile distant. Since there was about 5 feet drop from the bed of the pond to the water level of the sink hole the installation of a 12-inch sewer line from the pond to the sink hole solved the drainage problem permanently and reclaimed much valuable park land.

This sewer line was laid on a 0.5 per cent grade with manholes at each break in alinement. In crossing Polk Street, a 17-foot cut had to be made which required sheeting. A brick catch basin, with 1 inch vertical screen for preventing débris entering the sewer line was constructed in the park. Lateral ditches drained all the swamp land to the sewer.

The cost data for this work is as follows:

	Labor.	Material.	Total.
Excavating 284 cubic yards	$442.25	$13.19	$455.44
Refilling 284 cubic yards	120.76	.....	120.76
500 feet 12-inch sewer pipe	27.50	146.71	174.21
Total	590.51	159.90	750.41

From our experience in Chattanooga, it is believed that in limestone districts a great saving can be assured over surface drainage

FIG. 12.—VERTICAL DRAIN, CEMETERY POND.

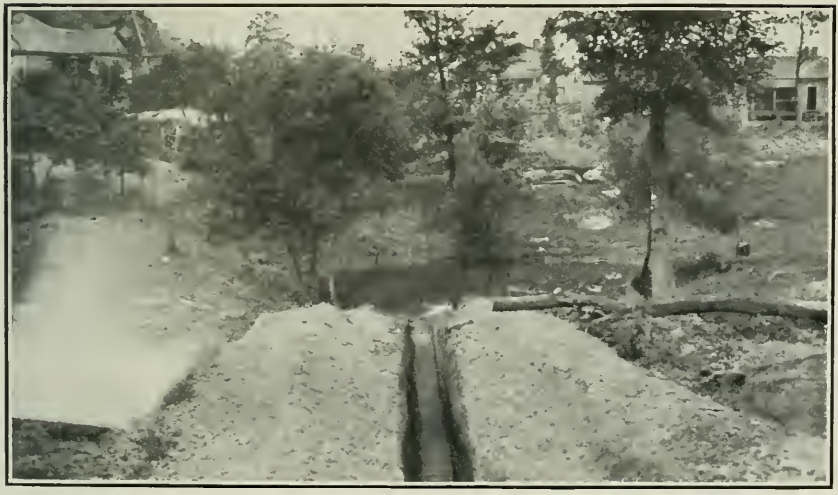

FIG. 13.—"SINK HOLE" INTO WHICH MONTAGUE POND WAS DRAINED.

by taking advantage of the seams in the limestone and constructing vertical drains to them. That there is a degree of uncertainty in connection with this work is admitted, but in view of the great saving in case of success as compared with the slight loss of failure, it is believed that possibilities well warrant the attempt.

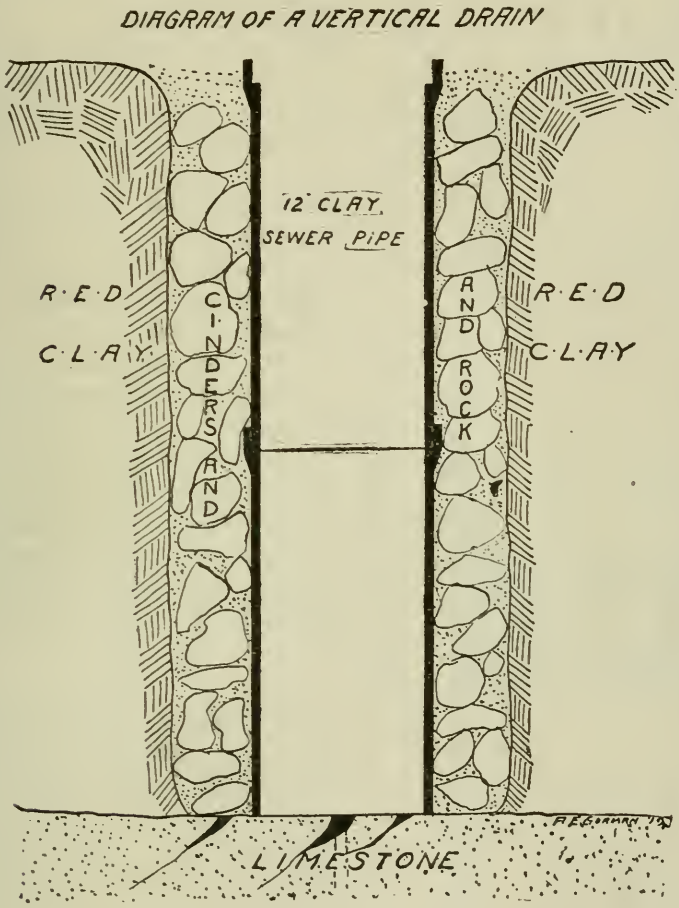

FIG. 14.

G. H. BISHOP, ASSISTANT SANITARY ENGINEER.

During 1918, 330 feet of vertical-drain wells were constructed at the Montgomery station. Five wells were constructed at an average depth of 55 feet, the total cost for drilling was $40, or 12 cents per foot for boring only. These wells were bored through stiff clay and were built before I came to the station, so all I know about them is their final operation. The clay at that station is approximately 40 to 50 feet in thickness. The wells were put down with an ordinary

pest-hole auger with sectional pipe extensions. No lining was placed in the wells and no evidence of caving was found. They drained about one-third of an acre each. Two types of heads were used, one of these was concrete and the other was built of wood at the station and cost approximately 50 cents each. A suggested change in the design of this box to facilitate the working, is to provide a clean-out lid over the inside screen, provide a spout to conduct the water into the well, and mount the entrance screens on frames to be taken out and cleaned. We visited these wells after each heavy rain and the screens were cleaned of drift. At the close of the season these wells were standing full of water although the screens were clean, showing that they were silted.

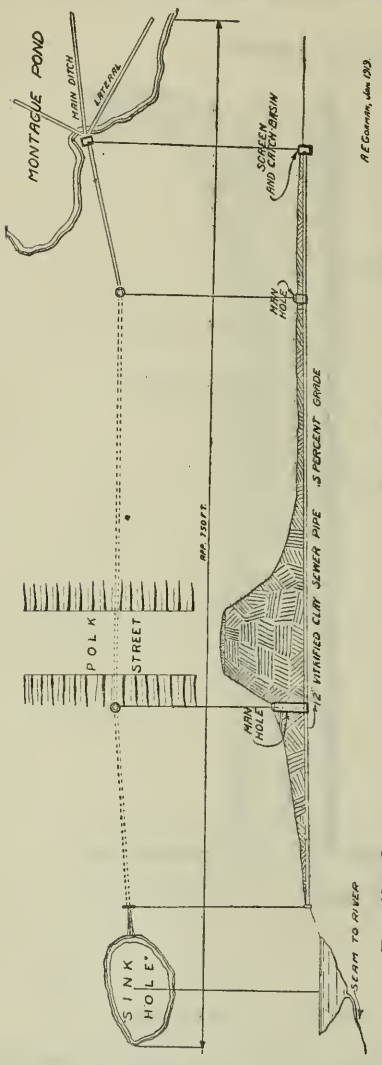

FIG. 15.—Diagram showing use of vertical drainage; Montague Pond and "Sink Hole."

The box mentioned above was made of 8 by 8 inch boards 3 feet long with two screens at the entrance, one-fourth mesh and fly screen. The main objection to this was that it had to be cleaned after each rain. Sticks and other débris had to be cleared away.

DISCUSSION.

Dr. WILLIAMS. Mr. Chairman, I have tried vertical drainage on a very small scale. There was a plateau with a very small pond in the center of it. This was 8 inches deep in rainy season, with water standing for months. We thought we would try vertical drainage. A terra-cotta well (8 inches in diameter) was sunk near the edge of the pond until a water-bearing gravel was found (30 feet from surface). The pond was ditched to this well. As the well filled the water slowly seeped away in the gravel layer. The pond dried and remained dry the balance of the season. I might say that this principle had been in use in Tennessee near Memphis for some years for

the disposal of overflow from small septic tanks. It always worked well in the summer months.

Mr. Stromquist. Mr. Chairman, we had some experience with the auger which Mr. Bishop mentioned. We had some difficulty with it. The handle was in sections 6 to 8 feet long, which were connected with ordinary couplings, and after it had been used for a while the threads wore out. We remedied this by getting new pipes in sections 10 to 12 feet long, with couplings through which holes were drilled, so that sections could be connected with pins or bolts. A special handle was made which could be clamped to the pipe at any point desired. In several places where we tried to use the auger we encountered a cherty clay and found that it would not work in such material.

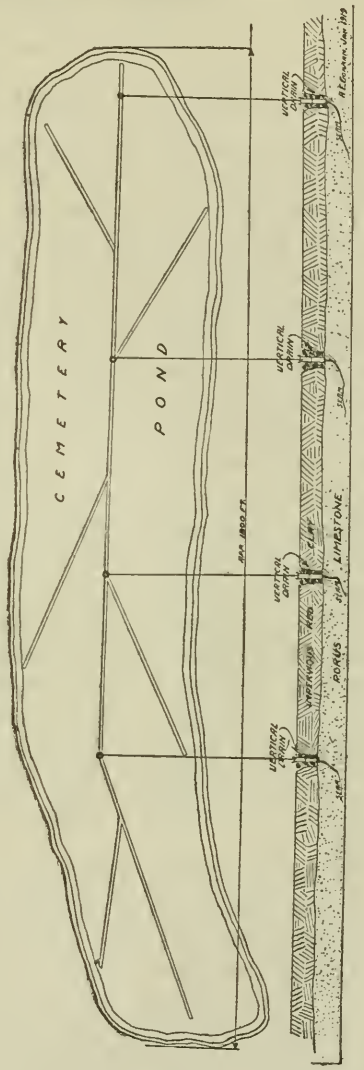

Fig. 16.—Vertical drains, Cemetery Pond.

In regard to the labor cost of our vertical drainage we paid laborers 30 cents per hour, or $3.30 per day, for 10 hours, and foremen $6.60 per day. Since we worked smaller gangs on the vertical drainage than on the ditching the proportional cost of foremen was higher, ranging from 20 to 25 per cent of the total labor cost on the vertical drainage as compared with an average of about 17 per cent of the total labor cost of all the drainage work, including the vertical drainage.

Dr. Carter. The next subject on our program, "The flight of Anopheles," will be opened by Dr. Griffitts.

THE FLIGHT OF ANOPHELES.

T. H. D. Griffitts, Assistant Epidemiologist.

This war was the first in which our country has ever been engaged, when we knew the means by which malaria could be controlled. More than once history records failure and even disastrous abandonment of military expeditions as a result of malaria. At the time of the Spanish-American War Ross and others were just developing and demonstrating the fact that malaria was, or is, transmitted by mosquitoes. From the time of Ross's early positive work down to the present—a score of years—there has been developed a knowledge concerning the transmission and the prevention of malaria that probably is as exact as, or even more definite, than has been the case with any other communicable disease. Next to the fact that certain mosquitoes carry malaria from the infected person to the uninfected is the problem of the distance of their flight from the places where they are produced, so as to be transmitters of malaria. In other words, what is their distance of flight, not only when in quest of blood, but subsequently when they may be infective. We were fortunate, therefore, when confronted with the mobilization, training, and embarkation of many hundreds of thousands of our soldiers in malarious sections, to have some definite knowledge as to the distance of flight of at least one species of American Anopheles (*A. quadrimaculatus*), the one that is now generally regarded as the most important vector of malaria in the greater portion of our malarious districts.

So far as I know, the first demonstration of distance of flight of Anopheles by means of marking and subsequently finding the stained specimens was that done in Panama with species different from the species in the States. Prior to 1916, distance of flight was conjectural. Even some of our leading authorities said that by cleaning up Anopheles breeding places for a few hundred yards about human habitations, malaria could be controlled.

As I have said, fortunately it had been determined by staining specimens, liberating them, and finding them again. The first specimen with the stain on it was found at a distance of 5,565 feet, 285 feet more than a mile away, on the second day after its liberation; and other stained specimens were taken at varying distances during the 10 days following liberation. This experiment was done in the

vicinity of an impounded water area, where there was a very great *Anopheles quadrimaculatus* production. It had been observed that houses as far as 1¼ miles from the pond were infected, and it was more than probable that *A. quadrimaculatus* found in these huts beyond where the stained ones were found had flown this distance from the same area whence the stained ones came.

This definite work done by the little band of Public Health Service workers there, was the basis upon which the zones of control were established in our extra-cantonment work. The mile limit from where barracks were located, or the same for the protection of civil populations was set as the standard. The results will show the wisdom of making this the general limit. Of course, where important breeding areas at even a mile and a half could be reasonably destroyed or controlled, and in the judgment of the officer in charge of control measures it is advisable to control, such should be done. Always bear in mind that the flight of an individual Anopheles may be the same whether she emerges from an enormous breeding area or from a small one, but flight from the large production area will be of greater sanitary importance.

There is much work to be done in connection with flight. That which has already been done should be regarded as the "first word" rather than the "last word." It is highly important that additional observations and experiments be made with regard to *A. quadrimaculatus* flight. We know little about the flight of *A. crucians* and *A. punctipennis*, while *A. pseudopunctipennis* occurs so rarely that it might be disregarded at this time. No worker in whatever capacity should fail to observe and to record everything that may point to definite knowledge as to the distance of flight of these species. We are inclined to believe that the *A. punctipennis* does not generally fly far from her breeding places, which incidentally are numerous in nearly all parts of the South. As compared with *A. quadrimaculatus*, she is seldom found in occupied houses. Does she enter houses and infect the inhabitants and escape during the early hours? She bites on porches at night, but some of us believe, seldom does so in doors. If this is the case, it should be proven. What effect has availibility of food or blood on the distance of flight? Topography and some other factors are touched upon in article on "Flight of Mosquitoes," published in Public Health Reports, with which, of course, you are familiar. As to flight of *A. crucians* definite knowledge is yet lacking, so far as I know. We must determine the distance of her contaminating flight. It is important, for in some sections, especially in the tidal marshes (and other places), this species predominates. I have observed one place in particular, namely, at Langley Field, Va., where it seems fairly certain that the *A. crucians*, heavily infesting a certain barn, came from salt marshes three-fourths of a mile away,

where this species was breeding freely. No breeding places closer were to be found at the time (early part of September, 1917), although farm ditches, then dry, had been filled with water earlier in the spring. The salt marsh was ditched and the farm drainage ditches cleaned out the following season, and the reexamination of the same barn also in the early part of September, 1918, showed only one *Anopheles crucians*, three men examining for as long a period as in 1917, when *A. crucians* were found by the hundreds. Of course, this is nothing very definite as to the distance of flight, but like other observations it tends to show that *A. crucians* in this instance were coming from a distance of three-quarters of a mile from their breeding grounds. Very much more work needs to be done in connection with the distance of flight of the three principal malaria carriers in the Southern States, and it is an opportunity, as well as the duty, of each and all of us to make every observation possible, and every experiment feasible to determine these very vital questions. I would urge every one on field malaria work not to fail to make complete notes of everything bearing upon this phase of the question, however insignificant the data may appear at the time. It's the mass of information that may result in very definite knowledge concerning the flight of malaria transmitters.

Dr. Carter. Mr. Le Prince has done some work on the flight of Anopheles. I will ask him to tell us something about it.

J. A. A. Le Prince, Senior Sanitary Engineer.

There are four Anopheles in the United States that we might consider as possibly the most important. Regarding the species in the West and in California, I know nothing of it at all except the fact that very little is known definitely regarding its usual distance of travel.

Regarding the study of flight of *A. crucians* and *A. punctipennis*, we must consider the habits of these two species. It is definitely known that *A. punctipennis* does not like to enter inhabited houses, possibly the *A. crucians* also are inclined that way, and if so we can not follow the same methods of making observations of these two species as we do in making flight observations in regard to the *A. quadrimaculatus*. In other words, the examination of houses will not necessarily determine the density of *A. crucians* or *A. punctipennis* that have made long flights. It will give us a very good idea regarding flights of *A. quadrimaculatus*. It may be that we will have to catch *A. crucians* and *A. punctipennis* adults biting human beings or possibly animals at known distances from their breeding places. We may definitely determine at some later period, and I am inclined to believe that such will be the case, that *A. quadrimaculatus* is responsible for most of our malaria. Up to the present time we have

been inclined to believe that the *A. punctipennis* does not generally fly far from her breeding places, which are numerous in many parts of the South. As compared with *A. quadrimaculatus*, *A. punctipennis* are seldom found in occupied houses. We are also inclined to believe that the more extensive the breeding area under most conditions the more lengthy will be the nightly flight of the *A. quadrimaculatus* from the breeding places.

To determine briefly the average flight distance of *A. quadrimaculatus* from a known breeding area make a sketch map of the vicinity showing houses, breeding area, etc., and temporarily eliminate other breeding areas. Classify houses in the vicinity into five groups, as:

Zone 1. Those within one-fourth mile of the breeding area.

Zone 2. Those within one-fourth to one-half mile of the breeding area.

Zone 3. Those within one-half to three-fourths mile of the breeding area.

Zone 4. Those within three-fourths to 1 mile of the breeding area.

Zone 5. Those within more than 1 mile from the breeding area.

Make a thorough examination in and under all houses, outhouses, barns, etc., for Anopheles. If the breeding area is prolific and extensive, we should expect to find large numbers of *A. quadrimaculatus* in buildings in zone 1 and a diminishing number as we approach zone 5. When beyond flight range we find no Anopheles in the buildings examined.

If the output of the breeding area is limited we may find few or no Anopheles in zone 3 or zone 4. This method of procedure is recorded in a United States Public Health Service reprint.

In regard to work in small communities it is often questionable as to whether it is necessary to extend control work as far out as a mile. By checking results of house infestation, as the work proceeds we can often determine the required radius of necessary control area. I know of many instances where the work was not extended a mile, where the breeding was light, and we reduced the malaria to practically nothing, and could find no Anopheles in the houses. So we must not cling to fixed distances in our work. In the rice-field areas we may find that we shall have to go farther than a mile with control measures because of long-sustained flights. In cases of light breeding we shall probably find many instances where it is not necessary to control beyond one-half to three-fourths of a mile. I know of instances where in certain districts the malaria-conveying Anopheles did not travel 1,300 feet in the direction of houses. Do not be discouraged in flight observations if some night the flight fails to appear. There may be 1, 2, or 10 nights where you will have flights from the breeding places to the feeding ground or

houses, and then some night the forward flight or return morning flight may not occur.

DISCUSSION.

Dr. CARTER. I will ask Mr. Tarbett to continue the discussion.

Mr. TARBETT. Mr. Chairman, an experiment to determine flight of *Anopheles quadrimaculatus* was made in the Lonoke, Ark., district in the latter part of August and early September. This flight was planned because of some observations made early in the season. In May, two of the rice fields in the district were flooded and about two weeks later *A. quadrimaculatus* were breeding in large numbers in these fields. At this time no other rice fields within the district had been flooded nor were mosquitoes breeding anywhere within the zone except in the two mentioned fields. At the time breeding was observed in these rice fields *A. quadrimaculatus* were found at various points throughout the city and district. Many were found at one point near the camp 1.7 miles from the rice fields in which breeding was occurring. As we were positive that there were no breeding places closer to this point than the rice fields, it appeared, that in this case at least, flights of 1.7 miles were taking place. Following these observations, flight experiments with stained mosquitoes were planned, but were not made until the latter part of August.

The experiments consisted of catching in one day about 6,000 mosquitoes alive, practically all of which were *A. quadrimaculatus*, staining, liberating, at a definite point, and after a lapse of 60 hours to then recatch at varying distances from the point of liberation and to examine for stain. In catching the mosquitoes for staining, lamp chimneys with inverted cones in one end, the other end being covered with bobbins, were used. The mosquitoes were transferred from the catching apparatus to lantern globe containers, the open ends being covered with bobbinet. About four-fifths of the mosquitoes caught for staining were caught in sheds and on screens at a point near the rice fields. Staining was made by spraying the mosquitoes within the lantern globe containers with an atomizer, a one-part aqueous solution of menthylene blue being used. One per cent eosin solution was tried but did not appear to give satisfactory results. Of the 6,000 mosquitoes caught for staining, but 4,000 were alive and active at the time of liberation.

The mosquitoes were liberated at a point near the rice fields to the southwest of the city and south of the camp. Sixty hours were allowed to elapse before recatching was started. This time interval was allowed, as we did not expect any flight the first night and were somewhat doubtful as to the extent of flight on the second night. During the interval between liberation and recatching, weather conditions remained constant, clear with only slight air

currents from the southwest. The recatch was made at different stations at quarter-mile intervals from the point of liberation extending to a two and one-half mile radius. In the sections outside of the city catches were made in every group of farm buildings within the area. Recatching was carried on for a period of 10 days, about 6,000 mosquitoes being caught on the first day, the total number caught being approximately 20,000.

There appeared to be quite a considerable diminution in the number of mosquitoes as the distance from the rice fields increased, being very numerous in those areas within one-half mile of the field.

Every mosquito caught was examined as to color, and the Anopheles were separated into types, male and female. Only 10 stained mosquitoes were found, 9 of these being on the screens of one house, three-fourths of a mile distant from the point of liberation, and the tenth one on the screen of one house (Dr. Geiger's), 1 mile from the point of liberation. These mosquitoes were caught on the first day of the recatch. From these experiments it would appear that the flight distance of 1 mile which has been generally used in our extra-cantonment work was apparently right.

Of the approximately 20,000 mosquitoes caught, over 18,000 were Anopheles, all of which were *A. quadrimaculatus*, no other species of Anopheles being found. The females predominated, being about 75 per cent of the total. Near the rice fields the *A. quadrimaculatus* were present in extremely large numbers.

Recatching was carried on in the buildings at the camp but mosquitoes were found only in hangars and unscreened buildings. *Anopheles quadrimaculatus* were rather numerous in the hangar which was used for amusement purposes.

Dr. L. L. Williams. Mr. Chairman, there is a question on the flight of Anopheles to any great distance. All experiments on flight have been from places of very prolific breeding. What is the flight range, in infective quantities, from places of mild breeding? How far should antimosquito work be carried when breeding comes only from such places as ditches and small streams? For instance (referring to subjoined diagram), here is a city on a neck between two rivers a mile wide, each. There is no flight across these rivers, other than Culex, in times of high winds. There is a navy yard 2 miles away and an embarkation depot not quite 2 miles beyond that. If the limit of work is a mile, then work would be inside the dotted line on the diagram. Inside this line the breeding places, though many, are not of a very prolific nature, being but few ponds and many small streams. Is it necessary in such a place to go the full mile; would not a closer limit (full line) of, say, one-half to three-fourths mile be sufficient and much cheaper? Outside of this mile zone is

found an area of enormously prolific breeding—old phosphate mine pits. These are about 1½ miles distant. Breeding is so heavy that it seems probable that many Anopheles from here must reach the depot. Would it be wise to stick to the arbitrary mile limit to drain and oil or be guided by local conditions and drain these pits and drain and oil only inside the three-fourths-mile limit?

Dr. Metz. Mr. Chairman, I have jotted down two or three things that I would like to mention. I think possibly it is important that

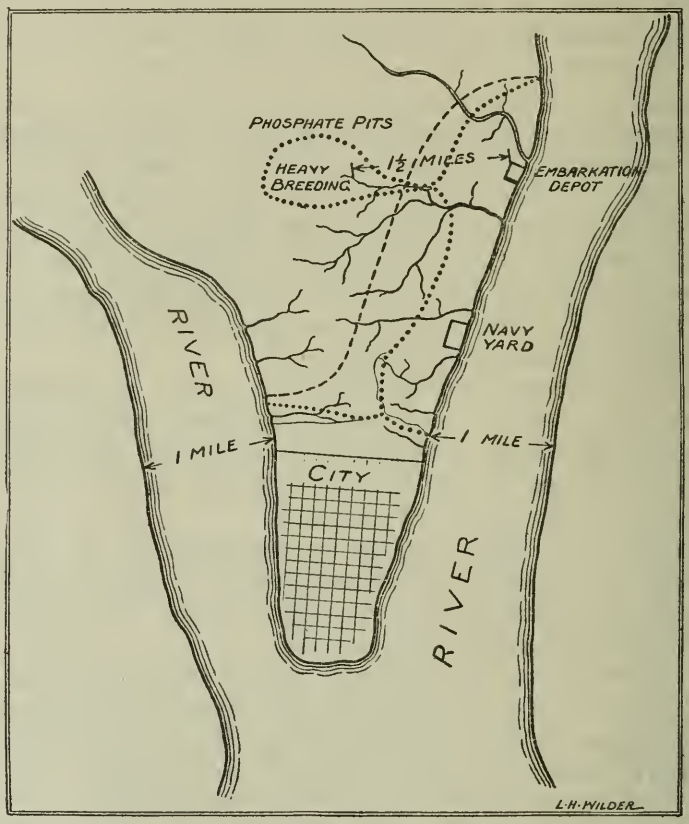

Fig. 17.—Diagram to illustrate query of Dr. Williams (p. 77).

more attention be paid to *A. crucians* than has been the case in the past. Another thing that has not been worked out fully, I think, is the part that topography plays in influencing the flight of Anopheles. Apparently Anopheles like to travel along low, wet places—ditch lines, etc. Over high, dry country they do not seem to go so far. I think this ought to be kept in mind. A question has also come to my mind several times as to the effect of the stain on mosquitoes, in connection with flight experiments. I do not bring this up as a criticism of the staining experiments, but simply to suggest the

desirability of obtaining a better method. If some one can think of a scheme that will enable us to identify Anopheles without having to catch and stain them, he will have found a method that will allow us to determine the natural flight. Mosquitoes do not naturally go through the operation that we put them through. There is also the question as to how far an infected mosquito will fly. Is the distance of flight similar to that of the noninfected mosquito? I also think that we may have drawn our line of work too close in, in some cases. In other words, I think that we ought to control heavy breeding places up to about a mile and a quarter, or from six to seven thousand feet. In the life of mosquitoes some never get more than a few feet away from the breeding places, but others appear to wander along certain lines and in the course of their lives may go a considerable distance.

Dr. CARROLL. Mr. Chairman, when is the best time to collect *Anopheles punctipennis?* At what time of day are they found on the wing and biting?

Dr. CARTER. In general, *punctipennis* is a porch biter and ordinarily will be found most abundantly in the early evening.

Dr. CARTER. We now come to the subject of "Rice field control measures," Mr. Tarbett.

RICE FIELD CONTROL MEASURES.

R. E. Tarbett, Sanitary Engineer.

The location of a flying field by the Air Service of the Army in the rice field district of Arkansas presented problems of malaria control not encountered elsewhere in the extra-cantonment work.

The field known as Eberts Field is located in Lonoke County, Ark., to the west of and adjoining the city of Lonoke. The field which has an area of 1½ square miles was built upon ground used during 1917 for rice culture.

The zone within which it was thought necessary to carry on malarial control work has an area of approximately 12 square miles, the field and the city being at the center of this tract. To the west and south of the field, rice is grown extensively and within the extra-cantonment zone at least 2 square miles are used for rice culture.

TOPOGRAPHY.

The area is flat prairie with slight slopes toward the existing streams and with undetermined divides. The top soil is a gumbo underlaid with a thick stratum of impervious clay.

POPULATION.

During the period within which control measures were carried on the population of the zone was approximately 2,400, of which number 1,500 were within the city. The number of men stationed at the field averaged about 1,200.

RICE CULTURE.

In order that the uncontrolled factor in the malarial control, rice culture, may be more readily understood, a short description of the methods of growing rice in the Arkansas rice district is given.

THE RICE FIELD.

The individual fields are inclosed by dikes or levees and within the fields are smaller levees constructed along the contours in order to maintain the water at an even depth. Through or adjoining the fields are ditches or small canals used in watering and draining the fields.

WATER SUPPLY.

In the Lonoke district the water for flooding the fields is obtained from deep wells, being pumped to receiving reservoirs from which it flows to the fields through the canals.

Flooding water is first applied to the fields when the rice has reached a height of 3 to 5 inches. The depth of the water is increased with the growth of the rice until a depth of 4 to 6 inches is reached which depth is maintained during the growing season. It is sometimes necessary to drain the field for short periods due to stagnation of the water (sour water) or to the presence of root maggots. From the standpoint of mosquito production we may consider that the fields will remain flooded from about June 1 until September 15, with some residual water areas after that date.

MOSQUITO PRODUCTION IN RICE FIELDS.

Rice fields constitute ideal breeding places since there is quiescent water and dense vegetation. There is at the present time no known method of control over mosquito production within rice fields, hence the location of rice fields within an area where malarial control measures are to be carried out makes the problem a complex one.

MALARIA-CONTROL MEASURES.

Three methods of control were carried out in the Eberts Field zone during the year 1918:

(1) Sterilization of carriers to prevent infection of mosquitoes.

(2) Screening to prevent access of mosquitoes to man.

(3) Limitation of production of mosquitoes as far as was practicable.

STERILIZATION OF CARRIERS.

Two blood indexes were made of every resident in the zone, one in March and one in May, the thick-smear method being used. In addition to these two indexes, an attempt was made throughout the season to examine every new resident entering the zone. From these indexes 90 carriers were detected. They represent a large amount of educational work in order to obtain the cooperation which was essential for successful results.

All carriers were not found on the initial examination. In five cases the second dose of typhoid vaccine precipitated a chill and in one case the same result occurred after a positive take with smallpox vaccination. In these cases just referred to negative results were obtained at the time the index was made. Another point of interest was that in 19 cases there was no history of chills and fever for the pre-

vious three years. Many other peculiarities of carriers developed during the course of the work which were of considerable importance if the maximum malarial incidence is required or desired.

All persons found upon microscopical examination to be carriers of the malarial parasites were treated with quinine in capsules by mouth, a dose being 10 grains per day. This treatment was followed for a period of 30 days after which the individual cases were requested to continue the treatment for a further period of 30 days. Of the total number, however, only 10 per cent continued the treatment throughout the 60 days. Since all carriers were checked microscopically each month there was but slight chance of failure in the control. All treated carriers were found to be negative throughout the season.

SCREENING.

In January a survey was made of every building in the zone and requirements for proper screening published. All buildings were required to be efficiently screened (16 to 18 inch mesh) and all buildings in which gatherings were to take place at night were required in addition to have vestibule screen doors. No open-air gatherings were allowed during the evening hours. No building within the zone was allowed to be occupied unless same could be properly screened. Monthly inspections were made of all buildings and the screening requirements enforced.

LIMITING MOSQUITO PRODUCTION.

Control over mosquito production was limited to a considerable extent since within the area were located rice fields within which *A. quadrimaculatus* bred to an enormous extent and over which breeding no control measures could be instituted. Such control measures were carried on throughout the season in all parts of the area, except within the rice fields proper.

CONTROL BY DRAINAGE.

The few streams within the area had no well-defined channels or beds, being for the most part swales. Surface drainage, including that from the rice fields, was taken care of by road ditches faulty in construction and often without outlets. The work carried on under this heading consisted of cleaning and bringing to grade the existing ditches, the clearing and channeling of the existing waterways, and some work in the draining of old rice-field areas adjoining the aviation field. A considerable amount of ditching was necessary in order to drain swamp areas and to allow for the prompt removal of the water from the rice fields.

In all, 76 miles of ditches, varying from 8 inches to 2 feet in depth, were cleaned, graded, or newly constructed. The Martin ditching plow was found to be particularly adapted for work in this area. During the season it was necessary to go over all streams at least once in order that the growth of vegetation might be removed and the channels improved.

The cost of the new work varied considerably, the average cost per mile, exclusive of overhead charges, being $117.10.

CONTROL BY OILING.

Oil control measures were instituted with the commencement of breeding and continued throughout the breeding season. All water surfaces, exclusive of the rice-field areas, were sprayed at intervals of seven days. Due to the breaking of the rice-field levees and the discharge of water carrying large numbers of larvæ and pupæ, close inspection and frequent applications of oil were necessary.

Oil was applied for the most part by use of the Meyer knapsack spray can (Panama pattern), drips being used in but few places. The gang method of oiling was used.

The oil used was a fuel oil of a specific gravity 34 to 36, and having a trade name of "Gas Oil." It appeared to be particularly well suited for mosquito-control work. The amount of oil used totaled 10,345 gallons.

COST.

The total cost of the mosquito-control work, including all overhead charges, was $19,107.31, or approximately $1,600 per square mile of area.

RESULTS OF MOSQUITO CONTROL.

As stated before, absolute control over mosquito production, and particularly the production of *A. quadrimaculatus*, was not possible, since the rice fields were within flight distance of all parts of the area. The best that could be hoped for in this part of the work was the limiting of the production as much as possible. In this it is believed that some success was attained, if we may rely upon local information as to the conditions prior to the carrying on of the work.

RESULTS OF THE MALARIAL CONTROL WORK.

The comparison of the mortality and incidence rates of 1917 with those of 1918 brings out forcibly the results obtained.

In 1917 there occurred within the zone four deaths from malaria, giving a death rate of 160 per 100,000, while in 1918 not one death occurred within the zone. In 1917 the history incidence index, the

only available record, was 29 per cent, or 522 cases, whereas in 1918 only one case occurred. These results are conclusive proof of the efficiency of the control measures.

This work was not an experiment, and therefore no comparison can be made as to the efficiency of the various methods employed; but since it was impossible to reduce the malarial mosquito prevalence below the point of sanitary importance, it is probable that this portion of the work, while the most expensive, was of the least value. It should be borne in mind, however, that the psychological effect of the drainage work was a factor that played a considerable part in maintaining cooperation on the part of the residents, and did reduce the mosquito pest within the community to a marked degree.

TOTAL COST OF CONTROL WORK.

The total cost of the control work carried on during the year can only be approximated, since control work other than the mosquito work was carried on in conjunction with sanitary and experimental work. This total cost is estimated at $28,000.

RICE-FIELD EXPERIMENTS.

In connection with the work of malarial control, experimental work was carried on in two rice-field areas, each being composed of five 1-acre tracts or plots. These two areas were at some distance from each other. The experiments, which were carried on by Plankton Expert W. C. Purdy, were to determine, if possible, some method whereby mosquito production within the rice fields might be controlled without injury to the rice. All experiments were carried on at the two areas simultaneously, in order that comparisons might be made.

The experiments consisted of (1) control by oil, (2) fish control, (3) control by intermittent watering.

OBSERVATIONS AS TO EXISTING CONDITIONS IN THE RICE FIELDS.

Observations tended to show that *A. quadrimaculatus* and *Culex* bred prolifically, in about equal quantities and more or less uniformly over the entire area. That top minnows, while present, were generally found in the deeper water near the levees and at the inlets. That predatory insect larvae were present in sufficient numbers to constitute a probable factor in the destruction of the mosquito larvae.

OIL CONTROL.

The oil used consisted of a mixed oil, one part black oil and two parts kerosene, and the fuel oil before described. The appli-

cation of the oil by means of drips located at the point where water entered the field was unsuccessful since there was a pooling of the oil near the point of application with no appreciable spreading through the field. This pooling tended to injure the rice due to the climbing.

In order to effect a uniform distribution and the production of a thin film without injury to the rice the oil was applied by broadcasting oil-soaked sawdust. Dry red oak sawdust was used. Thirty gallons of oil to ten bushels of sawdust were used for each acre.

The results obtained were encouraging, breeding being controlled for a period of two weeks after application and this without any appreciable effect upon the rice. In this experiment the fuel oil appeared to give somewhat better results than did the mixed oil.

FISH CONTROL.

Gambusia were placed in two of the plots, 1,400 in one and 800 in the other. These fish were uniformly distributed throughout the plots but subsequent examination showed that all the fish were in the deeper and more open water along the levees and that they would not penetrate the rice. In one of the plots there was a reduction of 70 per cent in the numbers of larvae following the addition of the fish and this condition continued for some weeks. In the other plot there was but a small reduction at first with an increase in the number of small larvae shortly after.

INTERMITTENT WATERING.

Intermittent watering was tried and while this method removed the greater part of the water from the field absolute removal was impossible owing to the many depressions which will always exist. As the rice fields in this section are operated the removal of the water from one field simply transfers the point of production to a nearby area and in no way prevents the production.

From an economic standpoint this method of control is not feasible, since the costs of frequent draining and rewatering would be excessive and also due to the inability to rewater in time to prevent injury to the rice crop.

CONCLUSIONS.

Since the experiments on the control of mosquito production in rice fields has not as yet been completed no attempt will be made to draw conclusions.

Dr. CARTER. Mr. Shaw has been working in the rice field country around Lake Charles, La., and we shall be glad to hear from him.

F. R. Shaw, Assistant Sanitary Engineer.

Although I was not concerned directly with rice field control, I was confronted with the problem of the control of rice field drainage.

The rice field nearest the barracks of Gerstner Field was 4,700 feet in a southeasterly direction, and as far as we could ascertain it furnished by very few Anopheles to the camp, and these were eliminated by hand catching. From May 15, the date the service took control, until August 6 there was no other source of breeding, for the only standing water was that in a ditch on the west, and the railroad and highway borrow pits on the north and northeast. The extent of control during this period consisted of two man days of oil-spraying a week.

To the north and northeast of the aviation field there existed a swale about 1,000 feet wide, which terminated in a natural ditch of considerable size as it approached the west end of the field. This swale and ditch served to carry off rainfall and the drainage from rice fields five miles to the northeast. It was not possible to foresee the condition produced by such a combination and furthermore the people in the vicinity stated that in recent years the water had not remained there long. Also, the drought had baked the prairie earth and the cost of ditching appeared prohibitive.

Following the storm of August 6, considerable rainfall occurred and at the same time the farmers began draining the rice field. The area one-half mile north of the camp became flooded to a depth of 2 feet and in due time larvæ washed down from the rice fields. Repeated attempts were made to enlarge the ditch and extend it into the depressed area, but the depth of the water was too great to make any progress. It then appeared that the cost would be prohibitive and it was doubted if such an expenditure would be justifiable so late in the season. The bureau was called upon for advice and Dr. Carter and Mr. Tarbett were sent to investigate. They estimated that the cost of ditching would not exceed $5,000 and considered this expenditure advisable, so as to afford protection during the remainder of the season to the 1,500 men stationed at the barracks.

Because of the lack of transportation facilities, it was not advisable to ditch by dynamite or machines, but by taking advantage of certain existing conditions, these operations were made possible in a reasonable length of time. The flooded area was divided into three parts by railroad and highway embankments, the former having a 100-foot trestle and the latter a 60-foot bridge for the passage of water. A dam was built across the trestle opening, thus cutting off the flow of water and making it possible to drain the area nearest the camp. This dam was constructed by starting from one side of the trestle and gradually reducing the opening, the final five foot

space being closed by the use of sheet piling. This feature of the construction will be referred to later.

In 10 days an average crew of 24 laborers enlarged and graded 8,000 feet of the natural ditch, cut 2,000 feet of new ditch 5 feet wide by 2 feet deep, and cut several thousand feet of small laterals. The new main ditch work cost 11 cents per foot. As soon as possible the pools of water in this area was covered with oil, thus eliminating the greatest source of danger.

During this time such a volume of water had collected back of the dam it was apparent that the lower area would be flooded again if the dam was broken and the water allowed to flow freely. To control the flow the four centerpieces of the sheet piling were cut off at the level of the water, and driven down to such a depth that the flow through the improvised weir equalled the capacity of the main ditch.

Similar use was made of the highway embankment and the second area quickly drained.

Prior to the completion of these operations the camp authorities were advised of the breeding in the zone, and they conducted extensive hand catching in the barracks. No case of malaria existed in the camp, and no new cases occurred in the entire zone throughout the season.

H. R. Carter, Assistant Surgeon General.

Gentlemen, I am going to debate this subject to a certain extent myself. In the first place, consider the general proposition of rice culture. In 1917, when we first commenced this investigation, the estimate was made that there were about $40,000,000 invested in the production of rice in the United States, and it was rapidly increasing. It is an industry then that deserves attention if it has a sanitary aspect. In Italy where rice had been cultivated for generations it produces a great deal of malaria and the attempt to control malaria around the rice fields has been given up. Rice cultivation is not allowed within, I think it is, 2 kilometers of a village. If you read the reports of sanitarians of British India, rice culture is supposed to be deadly to white men susceptible to malaria. The same in Burma and Indo China. In the Malay States it is different. Their rice fields are less malarious than the hill country. In America, along the Atlantic coast, where rice was cultivated before the Civil War, it was not believed that a white man could sleep within a reasonable distance of the rice fields. The overseers and negroes had their houses at some distance away on the outlying foothills, and went to and from work in wagons. No one dreamed of sleeping where the mist—"the miasm"—arose from the rice fields. I think the malarial conditions produced by the rice fields has been the main cause of their abandonment on the southern coast. Except at one or two

places, where there is protection afforded by screening, it is not regarded as a white man's job. On the other hand, in Arkansas where rice culture has recently developed, the malarial condition is not bad. Von Ezdorf told me that at Stuttgart they reported from 20 to 25 per cent decrease in population each year. We do not consider that bad. In the Yazoo Valley and many other places the percentage is decidedly above that—in some 85 to 100 per cent. Yet the heaviest production of Anopheles ever recorded was recorded by Mr. Le Prince at Stuttgart. In one barrel, covering it with his coat, he counted 2,768 *Anopheles quadrimaculatus* imagos. No such record has ever been reported anywhere else. They do then breed *Anopheles quadrimaculatus* in the rice fields of Arkansas even if they are not especially malarious. Not only is it universally stated that malaria is not bad there, but a blood index made there in the last few years showed only 1.9 per cent of the people living in the rice fields as positive.

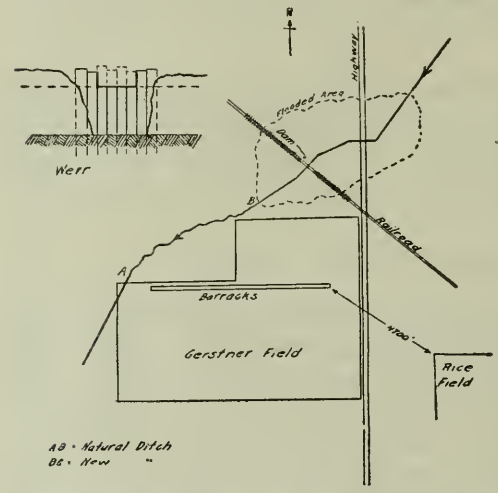

FIG. 18.—Illustration of control of rice field drainage.

In 1917 we commenced to study the malaria problem of the rice fields, starting in Louisiana in March, but the 6th of April we declared war and all investigations were stopped. We went into malaria control around the cantonments. The work has been taken up again by Dr. Geiger in California. It is stated that in California there is much malaria connected with rice culture. So much for the general proposition. I think it is fair to state that within the next 10 years this question will affect the investment of from $2,000,000,000 to $4,000,000,000 in the United States. If in any way we can control malaria in the rice fields, we should do it. That, of course, is the ultimate object of its study.

Let it be understood I am criticizing myself in this work of Mr. Tarbett's. Properly speaking, it was not an engineering problem. It was a biological problem. Three methods were used in attempting to control malaria. First, the control of Anopheles production by drainage and oiling; second, the control of access of Anopheles to man by screening, and third, the control of infecting the Anopheles by eliminating all parasites from human carriers. We were not trying out methods. We were trying our best to prevent those soldiers

from taking malaria. There is no question as to the success of the control measures. Among the civilian population 520 cases were reported in 1917, and in 1918 there was but 1 case reported. I quote from memory of Geiger's report. I repeat, there is no question about the control being a success—a brilliant success. Let us see if we can evaluate the different methods. I think, first, the attempt to control production had no effect whatever. I planned it—advised it—so I take the blame. It is a principle in biology that when the breeding place of an organism that breeds very freely is lessened by only one-third, as was done in this case, and the breeding place is very large, there will be no effect on production. When the breeding place is enormous something else besides the size of the breeding place limits the production; when the breeding place is practically without limit the size of the breeding place does not determine the amount of production. This is common sense. Geiger mentions that in catching mosquitoes for a flight he caught 624 *A. quadrimaculatus* at a single house at one visit. You can judge by that catch that production was not limited. Therefore, the control of production was not a factor. We will put this down as nil, I think.

Screening we will put down as to be considered. Screening alone would not have been sufficient to prevent malaria, but screening was unquestionably a protection, a protection not only to the person screened, but by keeping mosquitoes from him prevented their becoming infected from him, and hence the infection of other people not screened. I think, however, the effective factor was the control of the human host—the elimination of the parasite. This was done more thoroughly than usual. It was a good community; we had plenty of personnel and the people were anxious to help. Not only were they willing to take quinine but willing to come for examination, and whenever a carrier was found he got and took quinine. The population of Lonoke was nearly doubled. I know that the main factor in the elimination of malaria in Lonoke was the elimination of carriers—the control of the human host.

This probably is not of general applicability but it did apply here. The method was introduced by Koch in New Guinea and tried in German East Africa, but was given up there. It has been used in America by Bass in Bolivar County, Miss. His work has not been published, but he claims he got, and I am sure did get, excellent results. In the last analysis, gentlemen, I think we may consider that the control of malaria in the rice fields at Lonoke was not done by engineers, but by clinicians and biologists.

Discussion.

Capt. Gies. Mr. Chairman, as I understand it the practice in rice culture in the Arkansas rice fields is to keep the water on the fields about three weeks. If it could be drained off every eight days, the mosquito would be eliminated. Some of the rice growers told me that they thought it would increase the yield of rice to drain off and renew the water as often as that. If that is true, in spite of the increased cost of pumping to get that water on and off the rice fields once in eight days, would not the increase yield of rice as well as malaria protection warrant control by that method? I would like to have definite statistics, if possible, especially as to whether there is a decrease or increase in the amount of rice produced by the method of putting the water on every eight days instead of putting it on every three weeks or longer.

Mr. Hoskins. Mr. Chairman, I should like to ask if any consideration has been given to the plan of treating the water by some means as it is pumped that would render it unfit for mosquito breeding? If some chemical could be found to sterilize the water during the whole period of inundation (perhaps creosote) it would seem to be cheaper than changing the water on the fields once each week.

Mr. Tarbett. Mr. Chairman, there is one question in connection with the work that has been asked—cost. A considerable portion of the cost of the work was that of mosquito control. This was approximately $18,000, or $1,500 per square mile of area. The total cost of all malarial control measures can only be estimated, since the personnel engaged in this work, other than that engaged in mosquito control, also carried on the sanitary and health work for the station, including experimental work in the rice fields.

I would estimate the total cost of malaria control measures at between $25,000 and $30,000, or roughly, at $10 per capita.

At the time the flying field was established one of the requirements made by the Army authorities was that no rice should be grown within 1,500 feet of the field boundaries. This land was leased by the Lonoke Board of Commerce at a rather high figure, and they wish to be released from the expense during 1919. Our observations and results would indicate that the elimination of rice culture from this rather narrow zone had little or no effect in so far as malaria was concerned.

With reference to Capt. Gies's question as to pumping, I have no figures as to the cost of the pumping in the district.

Intermittent draining of rice fields is impracticable in this district due to the impossibility of removing the water promptly and economically; to the impossibility of reflooding the fields in suffi-

cient short time to prevent injury to the rice, and to the fact that the cost of any attempt at intermittent draining would be so great that rice could not be grown profitably.

As to Mr. Hoskin's suggestion that a larvicide be added to the water before the same is run upon the fields, this would be an easy solution of the problem if some chemical could be found which would have larvicidal properties and not be injurious to the rice. Where the water is pumped, as in the Lonoke district, it would be a very simple matter to introduce some chemical larvicide.

The question was asked as to the screening of the buildings in the field, with particular reference to the position of the doors and the direction of the prevailing winds. All barracks and buildings used during the evening had vestibuled screen doors. Practically all main entrances were on the west, or field side, and the prevailing winds during the summer are from the southwest.

Officers stationed at the field claimed that many mosquitoes were brought in by the ambulance. Ambulances were stationed during the day in the areas outside of the camp, returning at or just after dark. There is no question but these ambulances did bring mosquitoes to a certain extent.

Dr. CARTER. The size of the rice fields is an important question. The water stands on the rice in Louisiana, not for two weeks, but for 90 days. They have practically given up intermittent flooding because it is too costly. If you can not raise rice at a certain price it is better not to raise it at all. As to flooding the fields every 8 days, rice would be 60 cents a pound instead of 7½. With regard to treating the water, there is not enough creosote in the world to go into the water that is used on the rice fields. It would be impossible to get enough creosote to treat the rice fields. We may have to use the method in vogue in Italy, i. e., not allowing rice fields within 2 kilometers of the town.

The rice fields of Louisiana are not malarious. The malaria blood index gives less than 2 per cent.

Dr. CARTER. The next subject on our program is "Production of *A. quadrimaculatus* in potholes in streams and slowly moving water, etc." Mr. Fuchs will open the subject.

PRODUCTION OF A. QUADRIMACULATUS IN POTHOLES IN STREAMS AND SLOWLY MOVING WATER.

A. W. Fuchs, Assistant Sanitary Engineer.

Mr. Chairman, the larvae of *A. quadrimaculatus* have been found on several occasions in Green Mill Creek at points upstream where the tidal variation becomes very small. The creek here is 10 to 20 feet wide, with a good current except at the edges and in small indentations of the shore where the water is practically without motion. It was in such places that larvae of *A. quadrimaculatus* were found along with those of *A. punctipennis*.

The practical importance of determining whether *A. quadrimaculatus* generally breeds in flowing streams is evident in connection with antimalarial operations. While *A. punctipennis*, which in nature is a doubtful carrier of malaria, and known to breed in moving water, requires little attention, the breeding of *A. quadrimaculatus* in flowing streams demand that such streams be placed under control in antimalarial work.

Discussion.

Dr. Williams. Mr. Chairman, are the *A. quadrimaculatus* breeding in these places through necessity or selection? After you drain their breeding places will they breed where *A. punctipennis* would breed? We had sixty ponds in the area where I was located and every single one of them was drained. After they were drained we observed *A. quadrimaculatus* breeding in Big Creek where the surface flow was retarded by potholes and log jams; and late in the season even in small ditches. The question is if *A. quadrimaculatus*' breeding places of selection are removed, will they then breed in any numbers in those places where they had not been found before? This seems to have happened in Millington, Tenn.

Dr. Griffitts. Mr. Chairman, I am glad this subject came up, We were almost in a position to say that we never find *A. quadrimaculatus* in running water, and, notwithstanding what we have just heard regarding *A. quadrimaculatus* being found in moving water, it may even yet be a question of some other conditions rather than the current in the stream that determines whether it is *A. quadrimaculatus* or *A. punctipennis*. I have never seen *A. quadrimaculatus* in flowing water. Of course even on impounded water we have some current and I believe it will be well in all cases to take notice as to the

width of the stream, character of the vegetation as well as the rate of flow. There is a possibility of *A. quadrimaculatus* being washed in from nearby places into the stream. I believe that is possible in connection with the stream we saw yesterday in Wilmington. An important point is to note whether there are larvæ of all sizes in the stream. That might tend to show whether the eggs were deposited there or were washed from some pool. Keep accurate notes of the size of larvæ and as to whether they may have come from other sources. There may be a certain limit to the amount of current *A. quadrimaculatus* can stand. I believe a certain amount of current is necessary for the development of some kinds of larvæ. It has been found in developing certain larvæ under artificial conditions that current is essential to longevity.

Mr. Le Prince. Mr. Chairman, in the present state of our knowledge concerning the Anopheles it looks as if we may possibly soon reach the conclusion that it is unnecessary to control *Anopheles punctipennis* in connection with malaria control. If that becomes so, then possibly instead of spending $10,000 for ridding a community of malaria we may only have to spend $3,000 or $1,000. This is an important point. If it should be so, the question will come up as to when will a stream produce *A. punctipennis* only, and when will it produce *A. quadrimaculatus* as well as *A. punctipennis*. In investigating the subject, the question comes up as to whether during the dry season of the summer, when the stream becomes a dry bed with many potholes, would it become a *A. quadrimaculatus* breeder. In extensive investigations in northern Alabama, a series of potholes investigated produced nothing but *A. punctipennis*. We must make observations and determine the sanitary importance of potholes in stream beds. If any one has noticed the breeding of *A. quadrimaculatus* in running water or potholes he might refer to it.

Dr. Carter. I have on several occasions observed breeding of *quadrimaculatus* in potholes.

Mr. Shaw. Mr. Chairman, in the vicinity of Lake Charles, La., I have noticed *A. quadrimaculatus* breeding in potholes.

Mr. Allen. Mr. Chairman, we had just one case at Jackson, Miss., where we found *A. quadrimaculatus* in what would probably be called running water. Town Creek receives a lot of waste water and after rains the bed of the stream is filled with typical potholes. During the summer we found nothing but Culex. After the fall rains we hatched out larvæ from some of these potholes and they were *A. quadrimaculatus*. We went back and took some pupæ. We hatched them out and three of them were *A. quadrimaculatus*.

Mr. Woodfall. Mr. Chairman, I arrived at Raleigh after the mosquito season had started. The Department of Epidemiology has

done extensive work in determining the mosquitoes breeding in that vicinity. They reported to me that in two or three of the slowly running streams they had bred out *A. quadrimaculatus*. I very much doubted the statement and examined their specimens and in each case they proved to be *A. quadrimaculatus*.

Dr. Williams. Mr. Chairman, in Millington there was one large stream with a fall of 1 foot in 3 to 5 miles. The current was rather slow, a half mile to the hour, but a perceptible current. Part of the stream was clogged by logs, but that did not stop the flow. The current, however, was below the surface. The surface current practically stopped above each log jam. The stream contained considerable débris and algæ and even after that was cleaned out in the latter part of the summer we found *A. quadrimaculatus* breeding in these quiet surface waters of the moving stream, but practically no *A. punctipennis*. They were no Culex whatever. In the latter part of the season we found *A. quadrimaculatus* in the drainage ditches. Even in those ditches where the water was rather shallow it was moving and *A. quadrimaculatus* was found breeding.

Dr. Carter. In numerous investigations we have conducted it has been found that in the country above the falls of the rivers, in the neighborhood of large ponds, you do not find *A. quadrimaculatus* of sanitary importance in running streams. That statement stands—that in this region *A. quadrimaculatus* had not been found of sanitary importance in running streams. There are two factors which will have to be considered if you want to correlate our observations with those of these gentlemen. Our work on impounded waters, and Dr. Williams's question comes in here, led us to the conclusion that *A. quadrimaculatus* preferably bred in large ponds—that in the presence of large ponds they would not be found in running streams or potholes. On the Pee Dee, on the Broad River, at Stevens Creek, on the Savannah River, on the Yadkin, the Catauba, and above the fall we examined many thousands of larvæ hatched from streams, but not more than one-half of 1 per cent were found to be *A. quadrimaculatus*. We investigated conditions on the Coosa, Lock No. 12, and on Lock No. 17 of the Black Warrior. These investigations were conducted during several months of the years 1914, 1915, and 1916, and we found no *A. quadrimaculatus* of sanitary importance in the neighborhood of large ponds in running streams or potholes of running streams. I asked Von Ezdorf to notice this feature in his surveys. He found no breeding in free running water. Taylor of the Rockefeller Foundation wrote me the same from Arkansas. The observation stands for the conditions under which it was observed and for the locality where it was observed. How much it can be extended out of those particular localities is a question, and that is why I wish everyone would note the breeding place of the larvæ you develop.

If you develop larvæ from a pond, from a free running stream, from a cow track, record the species developed from each source.

I do believe that Dr. Williams has given the probable reason of the *A. quadrimaculatus* being found in his running streams—when she can not find a pond she will breed in the slowest stream she can get.

(At 12.30 o'clock p. m. the conference took a recess until 2 o'clock p. m.)

Afternoon Session, February 18, 1919.

Dr. Carter. Mr. Mitzmain has prepared a paper on hibernation. We will start the afternoon by asking Mr. Mitzmain to read his paper.

HIBERNATION.

M. B. Mitzmain, Biologist.

Mr. Chairman, winter is met by northern animals in four ways: (1) Dying, (2) migrating, (3) hibernating, (4) remaining active. Hibernation is a physiological state of dormant vitality in which many animals pass the winter—winter sleep in temperate zones and estivation or summer sleep in the tropics. Animals living in tropical regions pass the summer in many cases in a torpid condition and are said to be estivating. Here humidity is the indicator, as the animal body mechanism is active when it contains 55 to 95 per cent water, and slows up or becomes torpid when the water content is reduced.

In some forms the immediate cause of hibernation is not cold, for many animals go into their winter sleep some time before winter sets in. Hibernation and estivation afford means whereby certain non-migratory species are enabled to live through unfavorable climatic conditions which would end fatally in starvation or dessiccation were the animals to maintain their normal state of activity. The phsiological facts must be considered in studying the phenomena of habitual animal dormancy under conditions of winter and seasons of drought. Respiration and circulation are diminished. The digestive organs are practically inactive, so that little or no feces is voided during this period. There can be no sharp line drawn between normal sleep and the lethargy of hibernation beginning at the one end of the scale with what might be simply termed sleep and ending with animals that do not once wake up from the hibernating stupor until the time for its final termination.

There are all degrees of torpidity and likewise gradations between ordinary periodical sleep and hibernating dormancy. Insects pass the winter in all stages of development. Beetles, flies, wasps, bugs, and even some butterflies winter as adults, while a larger number of moths and butterflies, protected by a silken cocoon, pass the winter as pupae. Some of these also survive in the larval stages, and mosquitoes, particularly the temporary puddle inhabitants amongst the Culex and Aedes, winter as larvae. The Anopheles are known to pass the winter in the adult and larval forms, but never to my knowledge in the pupae and egg stages.

Hibernation in the mosquito is different from that of animals in a torpid state, inasmuch as it is a direct stimulus adaptation to

lowered temperature, and not in the sense of resting for purpose of seasonal rejuvenation.

A number of animals indulge in alternate periods of waking and hibernation. For example, the well-known mourning cloak butterfly and certain dipterous flies, including mosquitoes, are frequently awake or active on warm days in winter at a time when snow covers the ground.

There are likewise gradations of hibernation with sex distinction witnessed in the animal world. In the case of some of the social Hymenoptera it is only the fertilized queen wasp of the entire colony that survives the frost of winter, the remainder dying with the onset of cold in the autumn. In the case of an oft-quoted example amongst the mammals, with the bears of the northern latitudes only the female hibernates in the strictest sense, while the males go out now and then in search of food, although they sleep a great deal. It is pointed out that hibernation is more necessary for the female because she must remain quiet until her young are born and not expose her offsprings to the rigors of winter.

Thus we find a parallel in the anopheline mosquito. To compensate for the death of the male at the onset of the period of hibernation the female has been previously impregnated so that the perpetuation of the species is insured.

Partial hibernators, like the awakened anopheline mosquito after a full blood meal in winter, resume their apparent torpor, assume their sprawling position, and continue their state of dormant vitality. The rising temperature wakes the hibernating insect from its stupor, and the heat of the body very quickly reaches the minimum required for stimulation to activity.

As to the life stage in which the anophelines have been found hibernating, I believe this mosquito has not been discovered wintering in the pupa or the egg, but certainly in the adult and larva. Aside from absence of larval food, I am unable to account for the absence of pupae, but can give a plausible reason for the absence of eggs under winter conditions. Experimentally it has been determined that *Anopheles quadrimaculatus* does not oviposit under a temperature of 12.5° C., but it is found to commence egg laying at 13.5° C. These eggs invariably fail to hatch at temperature under 16° C.

In accounting for the disappearance of males during the period of hibernation, aside from any sexual provision, it may be explained by the absence of suitable food for survival. Vegetation being in a dormant state, food material is not available for the male mosquito. Whether there is stored food in the male's body commensurate to that found in the female has not been ascertained; certainly, that the male can withstand low temperature has been demonstrated

experimentally by keeping males in the ice box and providing suitable food. In one experiment it was found possible to maintain life for fully two months.

It has been my experience that artificially heated environments do not harbor or attract the hibernating mosquito. I have never seen anophelines either hibernating or resting in quarters in which the humidity has been substantially reduced by steam heat or other means. But we do find the insects wintering in stables warmed by the bodies of live stock and their fermenting dung.

In considering change in habits associated with hibernation, reference should be made to *A. punctipennis*, which ordinarily is rarely seen in houses, but during the winter is encountered in such quarters as vacated or unused rooms, however.

Our studies in the determination of the infectivity of the wintering mosquito are incomplete, the problem being more intricate as we progress. Each region has its own peculiar faunal conditions, and each year its meterological deviations and limitations; so that investigations must be considered individual, though interdependent.

Relative to seasonal influences, we are prepared to conclude that in the South, in the regions of the greatest malaria incidence, true hibernation does not exist, and that where true hibernation does exist the prevalence of the disease is not so vital a factor. These essentials must be taken into consideration in the interpretation of the biological and parasitological observations. We must appreciate that, in considering hibernation or winter inaction, man is not the only source of food and the supposedly resting mosquito is feeding occasionally in humidly warmed stables and animal sheds on domestic mammals and fowls. And who knows but that this means of feeding may be the manner for infected anophelines of disgorging their parasites and clearing themselves of the sporozoïtes they may harbor as the remains of the autumn's feed of human blood. This possibility has been borne in mind in our winter studies in efforts to collect material for dissection from sources other than human.

It was originally supposed that mosquitoes died when they had laid their eggs. The observation is probably true of anopheline mosquitoes which have hibernated in a fecundated state. On the return of spring they venture forth, lay their eggs, and die. It is not borne out by personal experience that the Anopheles survive through the power of the egg to resist the cold, or that the eggs will hatch after they have been frozen. Laboratory findings preclude this as a possibility, as fertile Anopheles eggs laid in the laboratory did not hatch at 4.5° C., but hatched at temperatures above 16.7° C.

The public health application under natural conditions, of low temperature tests of the laboratory, may be cited in mosquito dissections from Louisiana and Alabama, both regions at a latitude of

about 43 N. At one section infected mosquitoes were found as late as October 20, but none between this time and November 30; at the other, a mosquito was found with organisms on November 1. It was interesting to observe that sporozoïtes were seen in the former instance, but only one sterile-appearing shrunken oöcyst in the latter instance. This stunted oöcyst was recognized as similar in character to those seen in mosquitoes kept in the laboratory at low temperature for two months or longer.

Although it has not been determined what is the minimum lethal point for malaria parasites in the mosquito host, we have some evidence that these organisms will tolerate a temperature of freezing for a short period at least. King's experiments in New Orleans inform us that *Anopheles quadrimaculatus* can remain infected in the presence of 30 to 31° F. for as much as 2 to 4 days. Our field experience in northern Louisiana last year bears out the bench findings in a practical way. The first frost was observed on October 9, and again October 22. Infected anophelines were taken between these dates; two on October 11, one on October 13, one on October 15, and the last for the season on October 20. We must note, however, that in this region the normal biological activities of the mosquito hosts, up to this time, were not interrupted by the seasonal changes, for it was observed that male anophelines still abounded and occasional biting of females was experienced even up to November 9. In this district evidence of true hibernation was not manifest until November 23.

Theoretically and ideally, if proper measures for treating the early spring relapses of malaria were adopted, malaria would be reduced to a point sanitarily negligible, after having determined that hibernating mosquitoes do not harbor malaria organisms. This method of control (human source) would seem at first blush to be a ready solution, and would limit therapeutic measures to a small proportion of the community (except in such highly malarious districts as the Delta where 40 to 50 per cent of winter carriers are found); or even if an effective therapy could be determined on for treating gametocyte carriers the mosquito would be cheated of its rôle early in the game, and untold millions in actual dollars and economic value would be saved. However, to do this seems thus far as feasible as eliminating all Anopheles mosquitoes surviving hibernation by hand collecting, house fumigation, or other means; in other words, highly impracticable.

In this connection it is interesting to note that the brood of mosquito really responsible for disseminating the first spring infections is the previous year's wintering female, which, to provide nourishment for its fecund ova, attacks the usually convenient and accommodating human gametocyte host, and at the proper time transfers its pathogenic burden to a healthy individual. In support of this

statement we note that infected mosquitoes are discovered in early spring at a time when the new generation has not made its appearance, and only young larvæ can be found.

We have been led to believe that the first cold weather in November and December killed certain mosquitoes, notably the yellow-fever mosquito. This is no doubt true, for experimental evidence reveals the fact that 39° F. maintained for an hour or more is sufficient to cause the death of this species of mosquito. Like the malaria carriers, however, when the thermometer falls below 62° F. the Stegomyia becomes sluggish and will not feed.

A remarkable phenomenon is observed in the emergence of the late fall brood of Anopheles in the tremendous production of males —more remarkable when we consider that these November births are doomed to certain destruction during the hibernating period. In analyzing the probable cause it is fair to assume that nature makes provision for the perpetuation of the species by assuring the fertilization of all females which are to outlive the winter. Of approximately 1,000 female Anopheles captured during hibernation, in not one instance did a female deposit sterile eggs. During collecting trips, extending over four years in searching for the hibernating forms in sections where nearly true hibernation occurs, no living male Anopheles was found. In several instances dead males were collected in spider webs. It is to be noted that the predominance of males is the usual relation, this occurring normally in the proportion of $1\frac{1}{2}$ males to one female. In the November brood this proportion is increased to four or five for each female emerging.

Optimum conditions of life of parasite and host must be thoroughly appreciated when one wishes to evaluate the economic phases of malaria dissemination. Considering the extreme of latitude when regarding contraction of the infection, we speak of northern limits in geographical distribution of this disease; southern limits kept in the background. Instead of degrees of north and south biologists better appreciate isotherms and humidity records. It is purely a question of viewpoints—the human interpretation in biological sequences of habitation and migration on the one hand and the entomological view of response to stimuli of heat, cold, dry, and wet on the other.

The malaria plasmodium with its habitat in a warm host, and a mosquito being cold blooded essentially, it is only under limited ranges that the two-protozoan organism and insect host actively coordinate. The sporogonic plasmodia requires for its existence different temperature conditions than that in which the asexual phase flourishes. It will not thrive at the extreme temperature in which the asexual form has been cultivated (at 40° C. about) and conversely, the extreme low temperature at which the mosquito host

would thrive would kill the protozoan or at least make it innocuous, rendering it sterile. Dry heat will kill certain insects, such as fleas, body lice, and mosquitoes, e. g., fleas kept in an incubator at or near body temperature are killed in a few hours in the absence of moisture, while body heat, plus body moisture, provide a seemingly ideal environment. The humidity requirement for Anopheles mosquitoes is appreciated when we recall that mosquitoes of this species are not attracted to steam-heated rooms.

There appears to be a striking coincidence in the matter of optimum and minimum temperature requirements connected with the parasitism of the Anopheles mosquito. The minimum biting temperature is from 16° to 17° C. and the optimum from 28° to 30° C. while the minimum temperature for development of the plasmodium in the mosquito is generally 16° C. and the optimum 28° to 30° C.

The influence of temperature on the development cycle of the malaria parasite in the insect host is fully appreciated by most investigators. To derive the sanitary import of temperature relations, the temperature of protozoal development and the temperature of biting stimulus should be inseparable correlatives. It would be indeed folly from a public-health viewpoint to consider that which obtains under strictly laboratory conditions regarding growth of the organism in the mosquito as the criterion to guide the sanitarian.

For example, it is of scientific but of no sanitary interest to us to know that the malaria parasite will grow in the mosquito held in the laboratory subjected to controlled temperature by the aid of electricity and ice or ammonia refrigeration; it is a biological fallacy for us to expect the insect to maintain normal activities of parasitism under similar conditions in nature. The work of older investigators in temperature experiments with Anopheles and plasmodia is illogical in their epidemiological application on account of subjecting their experimental mosquitoes to a sudden change of temperature of as much as 8° to 22° C. immediately after engagement. This could not be expected to occur under natural conditions.

In the work of American investigators, notably King, it is indicated that exposure to low temperatures for a limited period does not affect the viability of sporogonic forms, assuming that provision has been made for the mosquitoes to develop sporozoïte formation. The developed sporozoïtes may survive several days of freezing temperature but the period of dormant vitality is limited because the food material, the hæmoglobin obtained by active feeding is required to insure viability. Then, to, activity in the protoplasm of the Protozoa at low temperature ceases and the parasitic organisms, although retaining their morphology and normal appearance, are not viable at the time when the mosquito becomes an active parasite with the rise of temperature.

Regarding temperature influence in other low forms of life we find that temperature below the minimum suspends bacterial activities but is not very effective in destroying the organisms, e. g., infectious bacteria frozen in ice are as active as ever after the temperature is raised. Only after prolonged exposure do extremely low temperatures injure bacteria. High temperatures beyond the optimum, on the contrary, lead to rapid destruction of organisms, both bacterial and protozoal.

This loss of infectivity through temperature change is significant in relation to hibernation of infected mosquitoes. Much can be explained if it should be definitely proved that mosquitoes procuring gametocyte bearing blood before winter sets in may become innocuous as a consequence of hibernation conditions. Thus far, however, in all our laboratory efforts we have not solved the important connection with life during hibernation because of the short length of time we have been able to maintain mosquitoes after their infection.

We are not prepared to state that in countries in which there is a cold season fresh malarial infections do not take place; the infection of the next season is started from the relapse of a previous infection and that the plasmodium of malaria can not retain its vitality in the mosquito during the hibernation of this insect.

The malaria parasite will not develop in the mosquito at low temperature. Therefore, the sporogonic cycle under circumstances of hibernation is considered improbable.

It is no doubt true that in many sections following the winter months malarial fever has in numerous cases disappeared and that only a rare human carrier is present to supply the rejuvenated mosquito with suitable parasites to carry on the pathogenic cycle.

Many authors discussing cessation of infection during the winter place significance in the fact, if true, that the female mosquito does not make a meal of blood just prior to hibernating, asserting that such nourishment would militate against the life of the mosquito, inasmuch as it causes the development and ultimate extrusion of ova which would terminate the life of the insect. I believe this is not the case and if it is, is not vital or significant. It is well known that occasional biting occurs especially upon animals housed in well-protected stables and also upon human hosts. It must be remembered that a torpid condition following blood engorgement resulting from winter feeding is accompanied by a physiological lethargy preventing the blood mass from becoming readily assimilated.

The discussion of hibernation would be incomplete without reference to the latest probable date of infection of the mosquito host. It is interesting to note that following two frosts about one week apart I collected an infected *A. quadrimaculatus* at Lenwil, La., in Novem-

ber, 1917. The single oöcyst found on the stomach wall of this mosquito would probably have not survived to maturity and to infectibility, as it appeared similar to forms seen in experimental infections when exposed to extreme low temperatures for a considerable period. This Louisiana case of latest seasonal infection in a measure confirms a former instance of the same sort in a mosquito collected in Talladega Springs, Ala., in November, 1915. Here, too, a single half-ripe oöcyst was seen in a *A. quadrimaculatus* which had already gone into hibernation.

We can not dismiss the subject of latest seasonal infection without citing its application from a public health viewpoint. A knowledge of the latest probable date of infection of the insect may be utilized in a practical way in determining when control measures may be discontinued because the mosquito is no longer capable of transmitting infection. Needless expenditures of public funds may be thus avoided, which is especially to be desired when funds are limited and not sufficient money is available for the purpose of merely curbing the mosquito as a pest. Although it may not be regarded as 100-cents-on-the-dollar sanitation, we can obtain the maximum value for allotted funds in this manner, e. g., presuming that in a certain area it was determined for the previous year that infective mosquitoes are not found later than November 1, allowing 12 days for the imago to become infective, 18 days to complete its transformation from the young larva, 30 days have supervened since control of the young stages should have been necessary. Therefore, mosquito eradication through oiling operations could be logically dispensed with on or about October 1 for the particular district under consideration.

Discussion.

Dr. Carter. Dr. Metz will open the discussion of this subject.

Dr. Metz. Mr. Chairman, I have very few remarks to make regarding my own observations on Anopheles hibernation up to the present time, but I have received answers to the circular letters I sent to some of you a short time ago, and these may be of interest. No Anopheles larvæ have been found to hibernate up to this time of the year. One case is reported, however, of a Psorophora larva found under ice and apparently vigorous. I believe this has also been found true of Anopheles larvæ, but not by any of the men whom I have interviewed. If anyone has any information along this line, it will be appreciated.

Mr. Baker. Mr. Chairman, a small spring-fed pond, about 20 feet long by 8 or 10 feet wide, was breeding *A. punctipennis* prolifically the latter part of the summer. On January 9 three of us visited this pond and made a thorough search for larvæ. The temperature of the atmosphere was 6° C. and of the water 12° C. Samples of mud were

collected from the edge and bottom of the pond, taken to the office and warmed, but in no case were larvæ found. Several other investigations—after warm weather—were made with the same result.

Mr. Le Prince. Mr. Chairman, I would like anybody here to tell me where Anopheles hibernate. I still have to find out. What is reported in books does not agree with field observations.

Mr. Woodfall. Mr. Chairman, in Raleigh, during October, we were able to find Anopheles larvæ in at least 12 or 15 breeding areas. Through December and January we have not been able to find a single Anopheles larva there. Prior to that time we got at least 400 during each week.

Mr. Allen. Mr. Chairman, at Houston, Tex., we have been making dips and we found Anopheles breeding in small ponds. Ever since we made the observation in December we followed up one or two places and we found a few Anopheles larvæ practically at all times.

Dr. Carter. I would like to state that there is a difference in climate that has a bearing on the subject. From the account at Houston the Anopheles live through the winter. There is no question but that in the southern part of southern United States they live all winter.

Mr. Mitzmain. Mr. Chairman, in answer to the question asked by Mr. Le Prince, although we know we find Anopheles on the walls of stagnant wells, animal sheds, privies, etc., as to where they hibernate, naturally is certainly a very important point. The only reference I have to that is my own experience in the work. At one time I found a few, very few, *Anopheles quadrimaculatus* 1½ miles from any habitat, resting at the time on some trees. When the small limbs of the trees were shaken these mosquitoes became active. I tested their activity by bringing a horse into the woods, when some of the disturbed mosquitoes came out and bit the horse. That, however, is not true hibernation, but then we might say that there is no true hibernation. As soon as the hibernating season sets in the young larvæ are probably disposed of, as is proven by the fact that after this time only full-grown larvæ are found. I do not believe we have ever found *A. quadrimaculatus* in the larval stage during the winter time. We know that the larvæ of other species hibernate.

Dr. Carter. Mr. Geiger, of Little Rock, reported a flight of Anopheles the 26th of February, in which the proportion of males was decidedly larger than the females. I left Little Rock January 28 in snow about 4 to 6 inches deep. No eggs laid after that time could possibly have developed by February 26. These must have been from eggs laid prior to that time, and this observation would imply that either the eggs or larvæ existed through the winter. I must confess, however, that I know of no similar observation.

We will now proceed with the next subject on our program—fish control. Mr. Wagenhals will please open the discussion.

FISH CONTROL.

H. H. Wagenhals, *Sanitary Engineer.*

The investigative work on fish control which was done at the Augusta station during the past malaria season was under the direction of Mr. S. F. Hildebrand, ichthyologist of the Bureau of Fisheries. The details of his investigations and experiments, the results obtained, and his conclusions are embodied in his final report to the Bureau of Fisheries. This report, I understand, is to be published by the United States Public Health Service in Public Health Reports. As my remarks are largely based upon Mr. Hildebrand's report, I will confine them to a few of the more salient features of the work and omit all possible details which can be better secured from a careful study of Mr. Hildebrand's report after publication.

While some few observations were made with other fish, the real investigations were confined to the *Gambusia affinis.* This was done because this fish was indigenous to the region, though not unusually abundant, and because in the extra-cantonment work the feature of control of breeding took, of necessity, precedence over that of purely scientific investigations.

In the use of fish as antimalaria control measures, the following points should be kept continually in mind:

(1) That the applicability of fish to control mosquito breeding is confined to comparatively narrow limits. Within these limits this method is extremely valuable and is at times the only practical one available.

Though this method is confined to narrow limits, I believe that there is within these limits a much broader field for the use of fish for mosquito control than is generally recognized. In other words, narrow as the limits may be, they are not as narrow as is generally supposed. At Augusta we have used fish, and in the future I would use fish under conditions to which, previous to this season, I would not have considered this method of control applicable. It has been found economical to control small puddles with fish, even though these puddles are subject to complete drying up. The frequency with which these puddles do dry up determines the economy of fish control.

(2) For the satisfactory use of fish of the size and nature that are adapted to mosquito control, it is essential that proper protection be given these fish to enable them to do their work. They are the

natural food of larger fish and must, therefore, be protected from them. This can be done by shelving off steep slopes to allow a very shallow refuge along the edges of the ponds or lakes, or by giving the small fish protection behind screens of such mesh as to exclude the larger fish but admit of the free passage of the small ones. In one instance in Augusta, it was necessary to thoroughly seine out the game fish in a pond before a sufficient number of the *Gambusia affinis* could be maintained to effect the proper control. Dynamite furnishes a quick acting substitute for the seine. (Before using dynamite for this purpose, be sure that it is not illegal in the State.)

In Augusta it was found that protection from human enemies was more important than protection from other fish. The top minnow is a very favorite bait for fishermen, who greatly appreciated the trouble we took in concentrating the top minnow in large numbers in places where they were easily accessible. We posted every pond with notices that the small fish in that pond were protected by the United States Public Health Service as a health measure and were not to be used as bait. Fishing by hook and line was willingly allowed.

(3) Under unfavorable conditions it is essential to give a certain amount of assistance to fish to secure proper control. This consists in the removal of vegetation along edges, floating débris, and algae formations. I will not discuss at this point data which we obtained on aquatic vegetation inasmuch as I note this is a subject scheduled on the program as a topic by itself.

I only wish to state at this point that the fish will by themselves overcome certain obstacles in the way of vegetation and floating débris, and that in many cases, in my own experience at least, more money was spent in the removal of vegetation than was necessary. The fish worked satisfactorily in much more dense vegetation than I had presumed possible. I would recommend that the extent of work necessary to be done be determined by inspection.

(4) On the whole much better and more comprehensive results were obtained at Augusta with fish control than was expected by either Mr. Hildebrand or myself at the beginning of the season. We found this method adaptable to conditions to which we had not expected to apply this method, and are satisfied that if a limited amount of assistance and protection was furnished the fish, they were able not only to replace laborers and oilers but also to be more reliable than the human labor for which they were substituted.

(5) The following statement may seem commonplace to men who have had experience in fish control, but to those who have not used this method I would give warning not to expect a complete elimination of breeding or absence of larvae. Throughout the entire season young larvae are to be expected and at times in considerable numbers.

The evidences of satisfactory fish control is the absence of any appreciable number of full-grown larvae or of any pupae.

(6) In conclusion, I would state that in Augusta we found (*a*) fish control a valuable, economic, and efficient method, (*b*) that certain factors entered into the efficiency of this method. For example, a large pond requires a great many more fish than a small pond. Do not expect a half dozen fish to control a mile of pond edge. If vegetation is present a larger number of minnows will be required than if the edges are ideal for their operation. If game fish are abundant, a larger number of minnows are necessary than if there are but a few of the game fish present; by removing the large fish, the number of top minnows can be correspondingly decreased.

One more point appeals to me to be worthy of special emphasis and that is the permanency of the work. The pond controlled by oil one season may be a most prolific breeder the following season, if not oiled. This will be the case in extra-cantonment zones where antimalarial measures are discontinued. If, however, the fish method is adopted there is every reason to hope that the second season will find the pond more densely stocked than the first season, and that fish will continue to control breeding even without any antimalarial campaign. This control will not be as efficient if no assistance is given in the removal of vegetation, etc., but I feel that regardless of obstacles we may expect that a high percentage of control efficiency will be permanently maintained in a pond well stocked with proper fish.

Dr. Carter. Mr. Komp is requested to continue the discussion.

W. H. W. Komp, Sanitary Engineer.

There are gentlemen here in the audience much better qualified than I am to speak on this subject. There are a few things, however, that I wish to refer to. Mr. Wagenhals has spoken of the protection to be given minnows from their human enemies. There is one case illustrative of that point which I shall bring up. A large nitration plant was situated on the edge of a march, into which the wash water from the gun-cotton washing plant was run. This discharge contained a mixture of nitric and sulphuric acids in 2 per cent strength. No minnows could be found on this part of the marsh, although they abounded in other parts. As a result, an area equal to three or four city blocks was breeding *C. sollicitans* profusely.

In the control work done in New Jersey it has been found that better results were obtained if both ends of a ditch could be discharged into a tidal stream. If ditches are cut across the marsh at intervals of 150 feet, with both ends connected to tidal streams, the rise and fall of the tide will cause the water to circulate freely in the ditches, and minnows can get into that marsh better. This has been emphasized by Capt. Gies when he spoke of the necessity of opening

tide gates when the water became stagnant behind them, and letting in a new supply of fish. My experience in Gulfport showed that wherever minnows were found in the ditches there was no breeding. We found minnows plentiful along the Louisville & Nashville right of way 2 miles from tidal water, and no wrigglers were to be found anywhere with the minnows.

Discussion.

Dr. Griffitts. Mr. Chairman, fish control of Anopheles breeding has its place the same as drainage, oiling, or other methods, but in order to be effective ponds or streams must be sufficiently clean of obstruction, or rather hiding places for larvæ, in order that the fish may gain access to the wiggle-tails. There are instances in which fish control can not absolutely be depended upon, and in which it is worse than useless to attempt to control by such methods. For instance, in new bodies of water, or in ditches that are not the normal habitat of top-feeding minnows, it frequently is better to rely upon oil, a method that is reliable, rather than to try the introduction of fish for the purpose of control during the first season. In salt marsh control I have seen places which were controlled by top-feeding minnows which seemed perfect, yet on another occasion, I have found ditches in the salt marsh blocked perhaps by a block of turf previously removed from the ditch, above which were found numerous Anopheles larvæ and likewise top-feeding minnows. It may be a question of their not having had sufficient time to have devoured the wiggle-tails, as perhaps they were carried in by tides after the wiggle-tails were hatched out in the water; but as a general rule, I think control in our salt marsh drainage is due to the combined influence of the rise and fall of water level with the tides, and the work of the top-feeding minnows.

In one instance I secured complete control in stock wells, where the water surface came within 4 to 6 feet of the top of the ground, and in which Anopheles were breeding freely, by the introduction of the top-feeding minnows, *Gambusia affinis*. This is not an original method of handling wells, as I believe Malloy and others applied fish control to wells successfully.

Just one word about an attempt to control Anopheles breeding in bodies of water where top-feeding minnows are already established. I doubt if it is possible to increase the number of top-feeding minnows in a pond or other body of water where they are or have been established for a considerable length of time. In other words, it appears to me that it is probable that a biological limit will have been reached in their natural habitat, and that as for increasing their efficiency in mosquito control, artificial propagation in hatcheries and adding them to the normal supply of minnows in the stream or lake will not be effective.

Mr. Le Prince. Mr. Chairman, I have seen a few ponds where we have had almost perfect mosquito control by fish alone in nature. I have one particular locality in mind—Hartsville, S. C. If any of you are ever in that vicinity I should like you to visit the lake. The surface of that pond is almost covered with vegetation, from shore to shore, particularly toward the lower end of the pond. The adult Anopheles in the vicinity. *A. crucians* mostly, are exceedingly numerous. At any time during the summer you can go to that pond and get very young mosquito larvæ. You can not find any larvæ, however, that are older than half grown. There are never any full-grown larvæ in the pond. I think that is the test of fish control. Five times during the year 1914–15 we went back to the pond and found these same conditions every time. In parts of Mississippi the malaria problem is largely a question of pond control.

In the vicinity of Jackson there is another instance of a pond with considerable vegetation in it where perfect fish control obtained. In that particular pond there are no mosquito larvæ, but every time a leaky boat is put on the lake you can find mosquito larvæ in the boat.

I asked the engineers of the service to state whether or not fish control had been observed at their stations in order to draw their attention to its value or to conditions where fish were unsatisfactory. In some instances we may state fish control is almost perfect. There are instances in which top minnows are not as satisfactory as might be desired, but in many cases they are of economic importance in reducing mosquito propagation.

A question was asked as to whether stocking a pond would be of use. At Norfolk, Va., there are a series of lakes from which the water supply of the city is drawn. We installed board fences across inlets, used such places as fish hatcheries, and at the proper time when we had large numbers of gambusia we put them back into the lake proper. We fed them well. The people living near the lake noticed a marked decrease in mosquitoes, and malaria decreased in that vicinity. There had been no decrease in malaria or mosquitoes before we increased the number of fish in the pond. I think we might save time and also get an idea of what the situation has been at the different stations by asking those who have noticed that fish control has not been successful to rise, and those who have noticed a marked decrease in breeding where the fish were present not to rise. We could then get an idea as to the conditions as observed. (There was no rising vote on this question, as requested.)

Mr. Bishop. Mr. Chairman, I am unable to stand up either way. I had one pond where the fish seemed to keep the mosquito breeding down. In others we had very little success. We had some top minnows sent to our station. We put a few of them into jars with some larvæ; the larvæ hatched, but the fish would not catch them.

Dr. Williams. Mr. Chairman, I have had the same experience in keeping larvæ in jars. After being in captivity they lie quiet and if you put fish in with the larvæ the fish will not touch them. The fish will not touch them unless they are moving. At Keltys, Tex., I once dipped 16 Anopheles larvæ and by chance included 1 gambusia. In about 20 minutes this little fish had eaten all of the larvæ, but it caught them only while in motion. As long as a larvæ remained quiescent the gambusia might bump into it and pay no attention. The slightest wiggle and it was immediately caught.

Capt. Gies. Mr. Chairman, I would like to ask if any of the gentlemen have had any experience putting the salt water killie fish into fresh water. I have tried the experiments for purposes of propagation but they die out.

Mr. Davis. Mr. Chairman, I have tried putting the salt water killie fish into fresh-water ponds for breeding purposes, but have never succeeded.

Mr. Delaney. Mr. Chairman, we had a condition at San Antonio, inland stream control, and by increasing the velocity of flow we secured control. We know that by increasing the velocity of flow by the usual treatment permitted greater fish action so that we could charge 50 per cent fish control and 50 per cent to increase velocity of flow.

It was noted that the large fish drove and confined the minnows to the banks and shallow waters, where they efficiently performed their duties.

Mr. Hoskins. Mr. Chairman, we had an interesting example of fish control in a recreation lake at Macon last summer. The lake has wide, shallow edges especially at the upper end and tails out to a considerable distance. Fish were not plentiful enough for control. We therefore placed floating booms across the upper parts of the lake and covered the part above with a heavy coat of oil, thus driving the fish to the lower part and increasing the effectiveness of fish control of these edges. The booms also prevented oil from reaching the bathing beach of the lake.

Mr. Pincus. Mr. Chairman, we had a series of fifty stock-watering ponds in which the water was very shallow and the farmers objected to oiling. We stocked them with fish and there was no further breeding.

Dr. Carter. Mr. Chairman, I judge there is no question as to the fact that certain fish eat all the larvæ they can get. There are often instances where the fish are prevented by floating aquatic plants from seeing the larvæ. The beach line of the Potomac River is thoroughly controlled by fish. The floatage on the outside is breeding Anopheles badly. I doubt if any one can give an answer either in the negative or affirmative as to whether we can get perfect fish

control. We have all seen places where fish controlled and places where fish did not control. Let the fish get to the larvae; that is most important. Mr. Le Prince brought out one point as to how you can tell when fish do control. If you find a number of small larvæ, none large and none developed into pupæ, you may be certain the condition is controlled by fish or predatory insects. This is the test of fish control.

Mr. Frank. Mr. Chairman, we had about the same conditions in the Mississippi coastal district. There was practically no breeding in any of our streams. The vegetation in some sections extends practically across the stream and yet there is perfect fish control. We can dip and dip and not get any larvæ. It should be stated, however, that the predominant vegetation is a kind of plant of which I do not know the name. The stem is one-sixteenth to one-eighth inch thick, extends above the water surface, and supports a leaf centrally. The distance between the stems is in most cases sufficient to permit minnow penetration. It should not be inferred that this condition is always met, but that it predominates.

Mr. Wagenhals. Mr. Chairman, I think that the discussion, as a whole, carries out the first point that I made—that is, the limited applicability of this method of control. You can use it in certain cases and in others you can not. Still there are conditions in which it appears to be the ideal method.

As to the question of helping fish by limited oiling, it is possible to maintain fish under a thin film of oil without injury.

With regard to the movement of larvæ in the presence of fish, we made several experiments at Augusta. We threw the larvæ away from the shore and observed their movements. The minnows in the ponds used were tame, and at times we noticed as many as half a dozen around the larvæ, even nosing it, but the larvæ remained absolutely still and were not molested by the fish. As the larvæ drifted toward the shore or any floating debris, if there was a fish between them and this refuge, they remained motionless, but as soon as they had a clear way, they would make a dive to safety. We spent an afternoon at one of our hatcheries and demonstrated this time and time again.

One of the main advantages of fish control is the probable permanency of the work. A well-stocked pond should operate satisfactorily for some years. In the Augusta territory, I have many prolific breeding places well stocked with minnows and confidently expect that the fish will continue to work after the Public Health Service has withdrawn.

Dr. Carter. The next subject for consideration is "Pond control," Mr. Tait.

POND CONTROL.

H. F. S. Tait, Assistant Sanitary Engineer.

In speaking of pond control I shall divide the subject of ponds into two classes, viz, natural and artificial.

Of the first named, the treatment necessarily being subject to the existing conditions, I shall only touch on the general treatment, which, in the main, consists of removal of aquatic growths, cleaning of pond edges, oiling, and fish control.

Of ponds in class two, or artificial ponds, perhaps none is a greater offender in the matter of mosquito breeding than the lumber mill pond of the South, and in speaking of pond control I will give the general treatment of such a pond, feeling assured that in the great majority of work to be done along these lines the methods used here will prove of general applicability.

Lumber ponds for the most part are formed by the damming up of small streams of bayous at some station of their course where the ground lends itself most readily to pond formation, regardless of the consequent effect of backing up of the stream. The result, as a rule, is large areas of swamp.

During the late war it was absolutely essential that nothing should be done to hamper the output of any mill on Government work, and the question naturally arose how to leave the mill pond, and at the same time drain the swamps.

The construction of a cofferdam at the upper end of the pond, as well as the log dam at the lower end with a flume bypass, solved this question. A storm spillway being provided, the pond remains filled at all times.

The edges of the pond, after clearing, were timber sheeted and back filled with oiled sawdust. This, with the removal of all heavy brush and log sinkers by chain drags, completed the job.

It is well to bear in mind that whereas the log pond itself may be breeding, the small streams and pools formed by pond seepage will more than likely breed more, being free from wave action and other influences.

Discussion.

Dr. Griffitts. Mr. Chairman, in pond control, whether by the method of fish control, oiling, or other methods, in order to be ef-

fective banks must be sufficiently clear of obstructions, or rather hiding places, for larvae in order to control them.

In the method of using a boom in oiling on pond control, using logs for booms is not dependable. It is difficult to get straight logs, and after being in the water for a length of time they become water-logged and sink, thereby allowing the film of oil to escape to the body of the pond. The boom we used was made of 4-inch boards, about $\frac{3}{4}$ inch thick, and with a similar board nailed along the edge of the first one, so as to have one board floating in the water

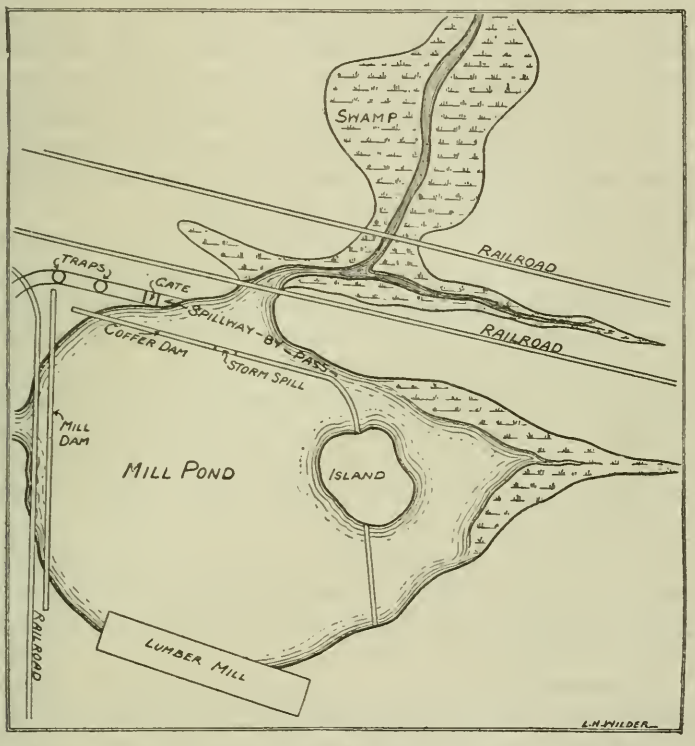

FIG. 19.—Rough sketch to illustrate paper on "Pond Control Work."

and the other standing upright in an "L" shape. This boom was fastened by means of wires attached to a tree or stakes at each end. This makes a light boom and will not become submerged. Pine needles and other small floatage will drift upstream and will become attached to the lower part of the boom. We found that Anopheles were breeding freely in this floatage, and it became necessary to clean the lower side of the boom and oil it each time the oiling was done above the boom.

Mr. Allen. Mr. Chairman, we had two ponds to control, both of them artificial log ponds. Fish control was relied upon to prevent development of any larvae and very good results were obtained. To briefly describe the ponds: McInnis Pond, area 10 acres, of which 6 acres were covered with a thick mat of green stalks of spiked weed. The total distance around the pond was 2,340 feet, of which 1,875 feet were raked. There were no bushes on the edge of the pond. A swath 1,875 feet long in this mat of green weeds and approximately 6 feet wide was raked from the edge of the pond, the remainder of the 6 acres being raked from a scow capable of holding 15 men and 5 tons of wet weeds raked from the pond bottom under the scow. The rakes used in this work were ordinary phosphate drags having 11-inch tines. A total of $159.87 was spent in clearing the weeds from this pond. The other pond, Newmans, is a long, narrow pond, constantly being dragged by the lumbering operations, and required only a moderate amount of brushing and edging. A total of $45 was spent on this pond.

Mr. Hardenburg. Mr. Chairman, during the season of 1918 officials of the Public Health Service in the Camp Wheeler extra-cantonment zone had six and one-half lakes to control, the half being the portion of one lake which lay outside the camp boundary. The lake perimeters ranged from one-half to 2 miles.

At the beginning, it was decided to depend very largely on fish control, the various lakes mentioned being abundantly stocked with top minnows.

In accordance with this decision, the program of lake control was carried on as follows:

First, a construction gang was put to work on each lake at the beginning of the season. They cleaned the edges of the lakes, removing overhanging grass and brush and raking out aqueous growths adjacent to the shores.

Next, maintenance gangs were put in charge of the various lakes. It was their duty to maintain the lakes in good condition. This was accomplished by various methods to be described later.

In all 5.57 miles of lake shores were cleaned by the construction gangs during the season at a cost of $1,170.54. The average cost per mile of shore averaged $208.36. This cost, of course, varied materially on the different lakes, some having good natural edges, while others were wooded and bushy.

The maintenance gangs maintained on the average for the season 4.75 miles of lake shores. (The remaining 0.82 mile did not require attention.)

The total cost of maintenance for the season was $2,254.48, or an average of $474.63 per mile. As the season lasted approximately six months, the average cost of maintenance per mile per month was

$79.11. These figures also include the cost of cutting lilies, which, however, was a comparatively small item, as only a few of the lakes had enough of them to require attention. Where it was necessary to deal with them, however, they were kept under fairly satisfactory control by occasionally cutting with a brush hook, until October, when a Ziemsen subaqueous weed saw was obtained.

In addition to the maintenance in good condition of the lake shores and the elimination of the lily pads, the maintenance gangs were required to oil the edges weekly wherever there was no objection to this course. Several of the lakes, however, were bathing resorts, and in these cases oil could not be applied in the vicinity of the beaches. Under these circumstances the worst parts of the lake shores were isolated by log booms. The booms rendered it possible to oil bad spots without letting the oil invade the bathing beaches.

Mr. Fuchs. Mr. Chairman, in this Wilmington district we have ponds of all sizes, varying in perimeter from 100 feet to 7 miles, of different soil and vegetation; being put to different uses, controlled by different methods.

Wherever possible, we are draining ponds. We tried to drain some ponds in sandy soils by vertical drainange by means of dynamite, but found the ground water so close up to the surface that we finally gave this up. Thereafter we drained by ditching or filling or a combination of the two. For small shallow ponds that would require a long ditch, filling is usually cheapest. For deeper ponds, which would require a deep ditch, it was often cheapest to use a ditch of medium depth, which usually reduced the pond area to small dimensions, and to fill up the remainder to the level of the bottom of the ditch.

In the case of stock ponds, where it is out of the question to drain it may be possible to reduce the necessary oiling area to a minimum by partial drainage so as to leave a smaller pond which may be deepened if necessary. In one case in this district we have a series of six ponds of large size. Partial drainage would require a ditch over half a mile long. One of these ponds is lower and deeper than the rest, and we are planning to drain the other five into it, leaving small holes in them for stock. In this way we hope to reduce the area of water surface 70 or 80 per cent.

Our largest pond is Greenfield Lake with a shore line over 7 miles long. It is an artificial lake formed by damming Jumping Run with its four tributaries. It is used as a mill pond and as a boating, fishing, and bathing resort. In no place is it over 12 or 15 feet deep, and it is flat and shallow some distance out from shore, so that a slight change in the water level produces a considerable change in the water area.

This lake is essentially a cypress swamp, with thick cypress growth covering portions of the lake as well as on the shores. The bottom is muddy, with an enormous deposit of decomposed vegetation. The water is clear, but has the dark color of cypress water. Over the greater part of the lake's perimeter there is short wiry sour grass for several feet above and below the shore line. This grass does not seem to afford mosquito larvæ much protection from the top minnows which abound in great numbers in the shallow water near the shore. Larvæ here are scarce, and those that we find are very small. The prolific breeding areas of the lake are the bays where the five streams that feed the lake enter. Here the vegetation is similar to the swamp growth of abandoned rice fields. There are thick growths of cat-tails and saw grass, and the water surface is thickly covered with lily pads and a close heavy growth of threadlike algae in which we found prolific breeding of *Anopheles quadrimaculatus* well protected from fish attack. There was also some breeding in the tiny pools on the lily pads.

Property owners along the lake would not, of course, permit us to drain it, so we had to control breeding mainly by oiling. An oil supply station was established at a point on the lake accessible to teams. A 250-gallon tank was used in which 3 barrels of kerosene to 1 barrel of black oil were mixed. The crew consisted of two men equipped with a small flat-bottomed boat drawing only 2 or 3 inches of water, which enabled them to keep close to the shore. One man maneuvered the boat while the other used the Myers Bros. 5-gallon knapsack spray pump. Where the shore was inaccessible by boat the sprayman got out and waded. The boat was a great timesaver, as the thick underbrush along the lake would have made spraying from the shore very slow and difficult. It took the crew just a week to spray the entire shore line. In this way, by working continuously, the lake was oiled once a week.

As an aid to oiling, copper sulphate was applied to the algæ growths. After several applications most of the algæ were destroyed. Also, after oiling had been in progress several weeks, we found that the oil was a great help in destroying the algæ and lily pads.

Shortly after control operations were begun on the lake, by arrangement with the operator of the mill the water surface was lowered about 18 inches. This reduced the shore line and lowered it to a point where the vegetation offered less protection to the larvæ. After the breeding season was over the water level was again raised, and will be maintained at high stage until the breeding season is on in the spring. In this way it is hoped to prevent the growth of rank vegetation along the shore.

The results obtained by oiling were very satisfactory. Before control was started every dip among the algœ growths brought 10 to 30 larvæ. After several weeks of oiling, in 60 dips not a single larvæ was found. On September 18, in 358 dips we got 7 wigglers. Again, on October 9, not a larvæ was found in 200 dips. On several occasions night catches were attempted near the lake, but we could get no adult Anopheles.

The total cost of oiling on the lake was $60 a week, or about $9 per mile of shore line per application.

Mr. Woodfall. Mr. Chairman, at Spartanburg, S. C., in the year 1918, we had under our control six ponds, two located within the city, two at Saxon, a small mill village north of the city, and two near the camp boundaries.

Spartanburg is a medium sized mill city with a normal population of about 25,000. This was increased to nearly 70,000 by the establishment of Camp Wadsworth in the vicinity. The camp was situated about 2¼ miles from the city on a rather elevated tract of land. The topography of this section is such that we had only a very few wet areas. These were caused by seepage water. There were no swampy areas.

Different methods of pond control were tried in the different ponds to determine which method would prove the most economical and require the least amount of work.

First, in considering the two ponds within the city; both of these were artificial ponds, one used to grow fancy water lilies, and the other to raise fish.

As mosquito breeding had already started at Spartanburg before the antimalaria work was commenced, rapid methods had to be used to keep the mosquitoes at a minimum. It was thought at first that the lily pads would have to be cleared and a clean edge established. Before doing this work however, a number of dippings were taken. No mosquito larvæ were found in the lily pond, due to the large number of top minnows. In the other, an abandoned fish pond, a small amount of breeding was found, mostly Culex with a few Anopheles. This pond was stocked with top minnows and in three days all mosquito larvæ had disappeared.

The third and fourth ponds, situated at Saxon, were found to be well stocked with top minnows. Here the edges were in a rather bad condition, but there was no growth in the ponds. Dippings were taken and a very small amount of breeding, mostly Culex, was found in protected places around the edges. As these ponds are used in connection with the mill, the owner was persuaded to properly clean the banks. After this time no mosquitoes were found throughout the entire summer.

The fifth pond, situated within 200 feet of the camp boundary and about 2,000 feet away from the thickly settled portion of the camp, was found to afford ideal breeding places. Not only was it in close proximity to the camp, but it was situated right at a contractor's construction camp, and also a camp used by the "M. P." who guarded that section. The pond was formed by erecting a dam to provide water power for a small grinding mill. It was about 60 feet wide and 800 feet long. Most of the banks were heavily wooded with alder growth, and extending out into the pond for 15 feet on each side was a heavy growth of water plants and weeds, in which the common flag seemed to predominate. The pond was found to be well stocked with top minnows; however, due to the situation of this pond, too much reliance could not be put in this means of control.

The banks were first cleared back for about 12 feet and then all the weeds were cut well below the water line. Arrangements were made with the mill owner to open the gate in the spill way every Saturday after finishing his grinding and to leave it so until Monday morning. This lowered the pond about 2 feet and brought all the water out into the clear, giving an excellent clean edge for the fish to act on. At no time were mosquitoes found breeding in this pond after these control measures were taken.

The sixth pond situated at Arcadia was less than 2,000 feet from a very thickly populated portion of the camp and also from the remount station. This was a mill pond flooding an area of about 350,000 square feet. A great part of this water had a depth of from 3 to 10 inches. This pond, for the most part, was covered with a heavy growth of water plants and water lilies. Arrangements were made with the mill people to lower the spill way 10 inches, thus eliminating the shallow back water.

It was thought that a drag or some other arrangement would have to be used to destroy the water growths, but before doing this 100 dippings were made and no mosquito larvæ found. It was also noticed that this pond was heavily stocked with top minnows. Nothing more was done, except to maintain careful inspection throughout the season, and at no time were mosquitoes found breeding.

A control pond for experiment purposes was found, which gave nearly the same conditions as to size, growths, etc., as the other ponds under control. Here a large number of the top minnows were caught and several times throughout the season more of the fish were caught, thereby reducing natural numbers. All through the season mosquitoes seemed to breed very freely at this pond.

To conclude, we found that top minnows gave us excellent mosquito control under conditions previously considered unfavorable. This might not hold true in all localities, but it did at Spartanburg,

and saved us a large amount of money by rendering unnecessary the removal of the water plants.

Mr. PINCUS. Mr. Chairman, the control of ponds and lakes in the 5-mile zone around Camp McClellan and near-by towns was held to be the most vital of the antimalarial operations, although it did not become the major part of the work. In our region the most serious aspect of the problem was the profuse breeding of *Anopheles punctipennis* in lakes and ponds.

These places were of many kinds; a 10-acre lake at Oxford Park, a 3-acre gristmill pond, several spring-fed ponds, over 50 stock-watering basins, and 150 clay pits just on the city limits of Anniston. No sawmill ponds nor gravel pits were encountered. In the treatment of these water areas, drainage was very seldom economical or feasible, only four ponds being so handled. In the main, reliance had to be placed on fish control, oiling, stripping of the banks, elimination of the swamps, removal of aquatic growths, and change in water level. Fish control by top minnows, *Gambusia affinis*, was found to be the most efficacious and in the shallow ponds containing no other fish, the minnows, after the banks had been stripped, gave perfect control. This was the method used for treating the 50 stock ponds where drainage, permanent oiling, chemical treatment, etc., were wholly inadvisable. The farm owners were notified to have their stock ponds cleaned, ready for the minnows, and failure to provide good edges to the pond would mean that it would have to be treated with oil.

The Oxford Park lake, a spring-fed basin, had a very marshy cove at one end which was eliminated by constructing a wood bulkhead along the shore line. This bulkhead or retaining wall was made of 2-inch planks, 2 feet in depth, coated with pitch and using posts of 4 by 4 inch timber. The cost of the bulkhead was close to 50 cents per linear foot of which 25 cents was for material and hauling. The section back of the timber wall was filled to above high-water level. During the construction, the water level of the lake was lowered 2 feet. The remaining part of the shore was stripped of its vegetation and a portion of the great growth of water fern and lily pads was raked out. The lake was then stocked with approximately 4,000 top minnows and a careful control inspection maintained through the malaria season. Scarcely any larvae were encountered in the frequent dippings made of this lake. The total season's cost for antimosquito work on this body of water was $600.

A spring-fed pond of about half an acre in area and with an overflow of 1,000,000 gallons per day was also bulkheaded, as at Oxford Lake, and further provided with a wooden spill way. Gambusia were introduced at the beginning of the breeding season, and a wire cloth screen provided at the outlet to retain the fish. The screen quickly

clogged with the large growth of algae formed in the pond and anopheline larvae became exceedingly numerous. The treatment applied then was to kill off the algae with a copper sulphate solution, blowing out the remaining plant filaments by a high-pressure fire stream and maintaining a complete oil film on the surface of the water. The algae and water fern had formed only where the depth of water was comparatively shallow—less than 6 feet—and when part of the pond bottom was covered with a 4-inch layer of cinders no growth appeared. The cost of constructing the bulkhead, backfilling, and clearing of the pond, in which 29 trees and stumps had to be dynamited, was $285, while the cost of copper sulphate treatment and oiling was $80 for the season.

Dr. Carter. The next subject for consideration is "Oiling." Dr. Griffitts will open the subject.

OILING.

T. H. D. Griffitts, Assistant Epidemiologist.

There are only a few points that I wish to emphasize in connection with oiling in the control of malaria. As to what methods are used depends largely upon local conditions, and the officer in charge of malaria control operations must of necessity use his own judgment as to whether he shall apply oil by drip cans, spray pumps, or otherwise; he must also select his methods of transporting oil and decide whether or not he will establish oil stations throughout his district, and the like.

It so happens that in the control measures in operation on the Virginia Peninsula it has not been necessary or advisable to use a single drip can, while I presume that at other stations they have been used with more or less satisfaction. The method of using the L-shaped boom was described in the discussion of pond control, to which reference is made.

In connection with oiling, there is nothing of greater value than thorough inspection. By covering our territory very thoroughly with a competent force of inspectors we were able to obtain complete sanitary control of Anopheles production, oiling at 10-day periods. In this way no doubt a great saving in oil, as well as in time was obtained.

Another point I wish to bring out, which I believe is an important factor in oiling, is that the spray should be directed as close to the water as possible. I believe in this way that we get the larvicidal effects of the oil best. We need to do more work with oil and larvicides to determine what materials have the greatest larvicidal properties. Only recently Lieut. Freeborn of the Sanitary Corps of the Army has done some experimental work with the oils generally used in mosquito control, and he has determined that their larvicidal properties bear a close relation to the volatility of the various oils.

It may be that the submerged drip can may prove more efficient than the drip can set high above the water; it is possible that the oil arising to the surface will still contain more lethal properties than where it is dripping, say 4 to 6 feet from the surface of the water and probably losing some of these properties. Such matters as this should be gone into thoroughly. In my territory it was not found advisable to have oil stations located at various points. We had one

central oil station at our malaria camp and the trucks were loaded at this point and oil carried to the various parts of the territory where needed. We had our men work in gangs with the foremen; most of you are familiar with the fact that negroes work better in gangs than by themselves.

I found oil-saturated sawdust, when thrown broadcast over swampy areas with many hoof prints, was a satisfactory method of applying oil.

Discussion.

Mr. Le Prince. Mr. Chairman, I would like to ask Dr. Carroll about the use of spray pumps in the New Jersey towns.

Dr. Carroll. Mr. Chairman, I think I will let Capt. Gies answer that question.

Capt. Gies. Mr. Chairman, we are using in New Jersey a pump attached to an oil can so as to get oil under pressure put on the ponds and you can spray a considerable distance with it. It is the best small pump that I have ever come across. The pump is manufactured by the Standard Stamping Co., of Marysville, Ohio, and used to retail for about $4 apiece before the war. It has a 3-foot hose connection. The hose is put into a barrel and the pump is worked by hand. It will cover a seventy-five or hundred foot pool from the shore.

Mr. Fuchs. Mr. Chairman, how far does it extend in spray form?

Capt. Gies. Mr. Chairman, it throws a coarse stream as thick as a pencil 50 feet or a fine spray about 25 feet.

Mr. Shaw. Mr. Chairman, the conditions in Lake Charles are different from any other station, in that there are no running streams. After the natural drainage systems were brushed and graded no water remained in them. We were concerned with street ditches which were supplied by house waste water, but it was not economical to distribute the oil by means of sprayers on trucks. Oil barrels provided with loose key spigots were placed on stands at convenient points throughout the territory. The oil sprayer was furnished an assistant who carried a 5-gallon can. In the morning, both these men would fill their cans, and proceed together until the supply in the knapsack spray pump had been exhausted. The pump was then replenished from the 5-gallon cans and as the sprayer proceeded through his territory, the assistant went to the nearest oil station, refilled his can, and returned to the sprayer before he was in need of more oil. For their own convenience, these assistants provided themselves with a soap box wheel cart, which facilitated the transportation of the oil and increased their own efficiency.

Mr. Delaney. Mr. Chairman, control at San Antonio was an inland problem, and owing to a three-year drought previous to our

operations no real difficulties were experienced. Oil was used only when breeding was actually found.

A light fuel oil known as Wichita Falls Light, of 25 gravity, was used, and was purchased by competitive bid. The cost of oil for the first six drums was at the rate of 13 cents per gallon or $6.50 per drum of 50 gallons capacity, which included the cost of the drum. We purchased 13 drums or 650 gallons at a total cost of $60.

The oilers were given a training which consisted of recognition of larvæ, the care and use of spray, when and where not to oil, and the recording of pertinent data. We were fortunate in securing men out of the area in which we worked, who had an excellent knowledge of the production area.

By interesting riparian owners in the use of oil, and the upkeep of their frontage, we were able to get these owners to use their own oil for oiling water intakes and other artificial containers on their property.

Our oiling costs summed up are as follows:

The average cost of oiling per lineal mile, per season, per stream, was $19.

The average cost of oiling per lineal foot, per season, per stream was $0.005.

Dr. Williams. Mr. Chairman, drip cans may be used over rapidly running streams; where the flow is sluggish they are not efficient and spraying should be resorted to. Where drip cans are used they should be watched very closely. They are hard to regulate when faucets of any kind are used. If the flow is regulated in the morning to say 20 drops per minute, then in the heat of the afternoon when the increased temperature has rendered the oil more fluid there will be a veritable stream flowing from the can. This wastes oil. If regulated in the afternoon, then in the cooler night hours when the oil is thicker, no flow is seen. Personally I believe drip cans are a nuisance and should be avoided.

In Texas I used drip cans and found them to be useless, although every effort was made to construct the best possible type. The cans were protected by inclosure within locked boxes; the faucets were made entirely of brass and allowed of very fine regulation. But the thickness of the oil varied so under varying temperatures as to render them worthless. The oil film was not continuous. Spraying was resorted to in order to control mosquito breeding.

In one place I have seen good results from drip cans. Browne, at Memphis, Tenn., suspended his cans over the streams on stretched wires which allowed of easy filling, as they were set on pulleys. Each can was perforated an inch above the bottom by a slit an inch long and one-quarter inch wide. In this was placed an ordinary lamp wick. The oil used was three parts kerosene and one part crude oil.

These cans dripped continuously until empty. Their drawbacks are the need for repeated filling and lack of regulations. They wasted oil, but did the work.

As I have remarked before, I think drip cans are a nuisance. Never have I found them entirely efficient. Where drip cans are used, spray pumps also may be used and will prove of far greater efficiency.

In the use of spray pumps I have found a procedure that saves considerable expense. This is the use of better transportation of both oil and labor. At Millington, at Hattiesburg, and at Louisville no attempt was made to provide oil stations at convenient intervals. Instead an oil tank (200-gallon) was mounted on a motor truck and filled each morning from a central station where the oilers met the truck. The truck then proceeded to the scene of operations. In oiling a stream, the truck and oilers stop near the headwaters and enough oilers to spray down to the next point that the truck can reach fill their cans and start oiling. As one finishes another commences. The truck proceeds to the next point, where more oilers are left. It then proceeds to the third point and drops the rest of the oilers. The truck now returns to pick up the oilers who commenced, conveys them to a point below the last and returns for the second gang. When they are working at still another point the third gang is picked up and the procedure is continued. In this way the distance that the oil is carried by each oiler is kept at a minimum and the distance that an oiler must walk while not spraying is reduced to the lowest possible.

This also reduces the necessary periods of rest. Oiling is hard work and even the best must rest frequently. By means of the truck the oilers are resting while being carried from point to point. Where sprayers are continuously afoot the average is four or five cans distributed a day. Where the truck is used the number distributed daily is from 8 to 10. Eight for small Negroes or old ones. Ten if the oilers are under 35 years of age and weigh over 180 pounds.

Mr. Spaulding. Mr. Chairman, it is generally agreed that almost daily inspection is required if drip cans are to be kept dripping. In the city of Columbia 46 of these cans were in almost constant use and rather detailed records were kept in order to compare cost of oiling from drip cans with that from spray pumps. A colored laborer who was able to read and write was assigned to this work. He was given a stenographer's notebook and an ordinary ice balance of 50 pounds capacity and was induced to buy an Ingersoll watch. Thus equipped he made the complete round of 46 cans in the city of Columbia each day. Upon visiting a box he noted the drops of oil per minute coming from the can, weighed the can and if necessary adjusted the rate of dripping, all of which items, together with the number of the can,

were noted in his book. When a day's inspection showed 15 or 20 cans required filling, the same laborer listed these cans and accompanied the truck on the filling tour. The can was weighed before and after filling, thus giving the actual quantities of oil used. In the office the inspector's notes were transferred to separate card records for each box.

The same general method was used on the drip cans in the zone around the camp but inspections were less frequent as it was not desired to keep these cans dripping constantly. It was our experience that considerable more oil was required on streams in the city limits than on those in the country. It is believed that the dust and dirt which absorbs and coagulates the oil is the cause of the greater requirements of city streams. We concluded from comparison of the costs that drip cans on this work were not as satisfactory as spray pumps. The records show considerable advantage in favor of the drip cans in the cost of application per gallon of oil but the application from drip cans was not always satisfactory and at times ditches which have been so oiled also had to be sprayed. Again it is certain that an increased quantity of spraying to be done, or rather concentration of the work which would result if drip cans were not used, would make possible a considerable reduction in the cost of application by spray pumps. A tabulated comparison is as follows:

Comparison of oiling costs July 1 to Oct. 18, 1918.

	City of Columbia.	Extra-cantonment.
DRIP CANS.		
Number of cans	46	65
Total miles oiled	12.1	22.6
Total gallons of oil	3,130	2,510
Total cost of oil	$427	$341.60
Total cost of oiling from drip cans	$929.43	$889.25
Cost per mile per week	$4.80	$2.36
Cost of oil per mile per week	$2.21	$0.94
Cost of application per mile per week	$2.59	$1.42
Total number of fillings	725	579
Average number of fillings per can	15.8	8.9
Average number of days between fillings	7	12.5
Average gallons of oil per can	68	38.6
Average gallons of oil per week per can	4.25	2.42
Cost of oiling per gallon of oil applied	$0.297	$0.364
Cost of oil per gallon in barrels	$0.137	$0.137
Cost of application per gallon	$0.160	$0.227
Number of inspections	2,648	1,061
Average number of inspections per can	57.6	19.3
Average number of days between inspection	2	5.8
Average gallons of oil per mile per week	16.2	6.9
SPRAY PUMPS.		
Total miles sprayed	225.25	392.50
Average miles per week	13.9	23.6
Total cost of oiling from spray cans	$853.91	$1,508.03
Total gallons of oil sprayed	2,041	3,670
Average gallons of oil per mile	9.3	9.35
Average cost per mile	$3.75	$3.84
Cost of oil per mile	$1.26	$1.27
Cost of application per mile	$2.49	$2.57
Cost of oiling per gallon of oil	$0.419	$0.412
Cost of oil per gallon in barrels	$0.137	$0.137
Cost of application per gallon of oil	$0.282	$0.275

Mr. Van Hovenburg. Mr. Chairman, while on the discussion of oiling, I believe the question of economy should come in. Shall we oil by inspection or by the calendar? Inspection is most important. Dr. Carter has impressed on my mind the economy of oiling by inspection.

Mr. Messenger. Mr. Chairman, I had a very concrete example of that when I started out oiling every week or 10 days. After two months of oiling I secured an efficient inspector. My zone can be covered by automobile, as it has very few fences and no marshes. It was possible for an inspector and myself to cover the zone once a week. The same force was used both for oiling and maintenance operations, and our force was sufficiently mobile so that when larvae were observed in pools the oilers could be loaded into a truck at once and started on the necessary oiling. We have been able to reduce the amount of oiling necessary by 50 per cent.

Sometimes we have a situation when one is justified in oiling directly from the truck. I tried that last summer, as we were oiling many roadside ditches. We used an ordinary pump with an extra hose connection. We had one man on the running board working the nozzle, and the other man worked the pump. It was fairly successful. However, there was not a sufficient volume of oil from the nozzle. I intend this coming season to get a pump of some kind which I can put directly into the barrel of oil, and with a larger nozzle. I think I shall try the pump Capt. Gies mentioned.

Capt. Gies. Mr. Chairman, I feel sure that would be successful.

Dr. Carter. The inspector could carry a man with him and attend to small places without calling in the trouble gang. Referring to Dr. Metz's suggestion as to the possible use of creosote, I believe that creosote has a big field of usefulness and just in this line.

Mr. Tarbett. Mr. Chairman, I had no trouble whatever in the Little Rock district in assigning men as oilers. The assignment as a rule meant an increase in the wages of 50 cents per day over that paid the laborer and was regarded by the men as a promotion, it being our policy to make oilers of the best men on the work. As a matter of fact, most of the men wanted to be oilers. All oilers were supplied with United States Public Health Service inspectors' badges. This was done in order that there might be no interference with the carrying on of work, and that they might act as inspectors as well as oilers. I might say here that all the oilers were white men.

At Lonoke, the gang method of oiling with negro oilers was used, but results were not as satisfactory as with the higher grade of men used in the Little Rock district.

Mr. Messenger. Mr. Chairman, I had negro laborers and gave them 10 per cent more a day when they oiled. They all kicked on

using the oil, so I had jackets of oilcloth made for them. They wore those jackets just two days. They were too hot, and the men refused to wear them. I never heard any more kicks about oiling.

Dr. CARTER. Mr. Van Hovenberg showed me yesterday a drawing of a jacket which I think will make the work of the oilers much less annoying than it now is. Has anyone else had any experience with the use of a jacket? Did you have much trouble with the laborers in assigning them to duty as oilers?

Mr. VAN HOVENBERG. Mr. Chairman, with respect to the jacket, it was designed primarily to allow some support in the small of the back, and to keep the can away from the lower end of the oiler's coat. A man can not be exposed in the hot sun using this oil without being scalded. We are trying to get waste material from automobile tops for making this jacket.

Mr. TIEDEMAN. Mr. Chairman, we found the men did not like the jacket. Owing to the fact that it must be made of some oil-proof material, it is very hot.

Mr. CLARKE. Mr. Chairman, instead of putting on jackets why not stop the oil cans from leaking? One of the main troubles with oil cans is that when they are filled too full the oil splashes out. By putting in the screened filler hole and by making joints tight with leather washers the leaking can be stopped and the oiler relieved of having to put on a heavy jacket.

Mr. TARBETT. Mr. Chairman, Mr. W. C. Purdy, Plankton expert, developed the use of oil soaked sawdust at Lonoke in connection with rice-field experiments.

The reason for and method employed in this work were discussed under the subject of rice-field control, to which reference is made.

No cost records were kept but based on 30 gallons of oil at 10 cents per gallon, two man hours broadcasting one acre, and assuming that sawdust would be fairly readily obtained, it is probable that the cost per acre per application would be approximately $4. On the basis of treatment at two weeks' intervals throughout the period that the water remains on the rice fields, the cost as applied to rice fields would be prohibitive.

Dr. CARTER. We used a great deal of sawdust at Quantico. It is particularly good for pond breeding where there is a great deal of floatage or vegetation. The result there was most satisfactory. We had no difficulty in drying sawdust. We simply took the top of the pile every few days and when we were ready for another lot the sun had dried it out again.

Has anyone used oil soaked sawdust in boxes or bags?

Mr. MESSENGER. Mr. Chairman, I experimented on a number of pools with oil-soaked sawdust in bags. I found on pools which had a

relative constant water level that the oil-soaked bags worked very satisfactorily for two months. After that it was necessary to replace with new bags, as the old ones would not soak up new oil. However, in intermittent pools I tried to use a bag, placing the bag on the edge of the pool. It was not successful because the oil soaked into the ground before the rains came, as the rains were too infrequent.

Mr. HARDENBURG. Mr. Chairman, the oiling device described, a box with two sides made of wire netting, filled with oil-soaked sawdust and sunk one-fourth to one-half its depth in the stream was found to be on the whole, somewhat less satisfactory in practice than drip cans, because it required more attention in order to get efficient results without waste of oil.

It was found that the best results were obtained with two gallons of oil to half a bushel to a bushel of sawdust. This would cover a stream with a film of oil for from 24 to 48 hours, depending on the velocity of the stream, the depth the box was sunk and similar factors. The best way to avoid waste of oil in filling the box was found to be to put the sawdust in a barrel, pour on oil and let it soak for from half an hour to an hour. It was found that if the oil was poured in the sawdust in the box, much of it would run out and be wasted.

The chief disadvantage connected with the device was the fact that it generally exuded too much oil in the first few hours and not enough subsequently. This was especially the case when the box was placed in a stream with a fairly swift current. To overcome this tendency, a great deal of attention was required, it having been found necessary to alter at frequent intervals its depth in the water.

In pools, a box would generally produce a good film over a radius of 40 feet. In windy weather the film might be extended to a radius of 100 feet. In streams having a comparatively high velocity, the water would be filmed with oil from 400 to 1,000 feet below the site of the device. The greater the velocity of the stream, the more oil required. A charge of two gallons of oil to a box would, as a rule, keep a good film on a slowly moving stream for up to 24 hours if the box was given sufficient attention, while on pools a similar charge would maintain a film of the area mentioned for 48 hours or more.

The foreman in charge of oiling expressed the opinion that oil in the boxes deteriorated in larvicidal quality after the first 12 hours, due to its exposure to water and air, as contrasted to that kept in drip cans. No satisfactory demonstration of the truth of this theory was obtained, however.

A modification of the device by which a burlap sack was substituted for the box was also tried out at this station. Except for improving its portability, no difference in operation or results was apparent.

In conclusion it may be said that while the device is certainly of value, it is believed drip cans give surer results for the same expenditures of oil and attention.

Dr. Williams: Mr. Chairman, some time ago, in Texas, at the suggestion of Mr. Le Prince, we reduced the number of seepage ditches being oiled by hand spray, by the use of a good sized piece of cotton waste dipped into oil and anchored in the bed of the ditch. The oil used was a heavy fuel oil, worthless as a spray, but particularly good for this purpose.

Dr. Carter: The sanitary officer at Quantico, Dr. Ebert, of the Navy, used sawdust in wooden boxes, with holes in them and afterwards in boxes of wire netting, and anchored them in the creek. They were efficient, but are not to be recommended on account of the expense entailed. This box had a funnel shaped cavity in the top, and it was kept filled with fuel oil. It was very efficient. The box was inspected once a day, and the inspectors by keeping this cavity full of oil furnished a continual drip of oil into the stream. Unquestionably it was efficient, but not economical.

Oiling is skilled labor. I think Mr. Tarbett was right in counting it as skilled labor. Whether by extra wages, whether by giving badges, or whether as Dr. Griffitts has done, by making friends, it should be recognized as skilled labor. As a rule white men are more dependable than negroes, and if men are dependable and skillful I do not believe the bureau would object to some raise in their wages.

(The conference then took a recess until 8 o'clock p. m.)

Evening Session, February 18, 1919.

Dr. Carter: We will limit our discussion this evening to one hour, and at the close of the meeting will retire to the Bijou Motion Picture Theater, where arrangements have been made to show the film Malaria Control. Mr. Van Hovenberg has prepared a paper on financing antimalaria campaigns, which we will now ask him to read.

FINANCING ANTIMALARIA CAMPAIGNS.

H. W. Van Hovenberg, Sanitary Engineer.

The success of organizing a malaria campaign depends on the amount of interest that may be aroused among those people interested in sanitation in general. I refer to city officials, members of chambers of commerce, women's clubs, civic leagues, large business enterprises, concerns seeking public approval, railways, hotels, and some individuals.

In organizing a campaign, go through such a list and determine which of the above would be most likely to assist in getting the program through. It is essential to solicit the interest and support of the medical fraternity in the campaign. Next in importance would come the city governing officers. Obtain from the doctors the malaria rate in the community and use this as a strong point in soliciting financial aid. It is necessary to establish the importance and necessity of malaria control in the minds of those from whom funds will be requested before asking for money.

If possible, organize a survey party, consisting of the city and county health officers, prominent physicians, chamber of commerce members, and city officers. Anopheles larvæ will, in most cases, be something they have never seen and will quickly arouse their interest. Demonstrate the difference between Anopheles and Culex mosquitoes in all stages of their development. After the field survey arrange a meeting, asking all those interested in effecting malaria control to be present, and invite the newspapers, if they did not accompany the survey party. This talk, or conference, for the business men, doctors, and city officers would end in asking for their indorsement and financial aid in supporting the campaign. Have a complete story for the use of the newspapers, and clippings from papers that might be given to the reporters at the end of the meeting. It may be necessary to call in the county or State health officers. If you are making no headway, I would advise telegraphing for Mr. Le Prince.

Arrange for an evening lecture, illustrated if possible, and be sure to allow the medical profession and the city officers to do most of the talking. It may be possible to secure financial support from the cities by having them furnish labor instead of cash. I would advise this procedure anyway because the city will feel more respon-

sible for the success of the campaign. On my railroad malaria work we have offered to cooperate in malaria campaigns in the cities along the line, in different ways. In some cities we have furnished the engineers advice and inspection only, and the cities have furnished all labor and material required. Again, we have offered to pay half of the total cost of the work. In some cities we have asked for definite appropriations, offering on our part to bear all expenses above the amount asked for. We have offered to take municipal script instead of cash.

While sanitary engineer in charge of malaria control work in a city of 120,000 population I employed a man whose sole duty was to organize and maintain the interest of gangs of boys and girls, each with leaders, which were organized in the school districts. They were to inspect all premises in their district for breeding places of non-Anopheles mosquitoes and report same to the health department for remedy. These campaigns among the boys and girls cost only a small amount in prizes and eliminated practically all Culex, breeding places, in the city, and may have been a large factor in convincing the people of the success of the malaria campaign due to the enormous decrease in all mosquitoes.

Looking to the future we must work to control human actions which are responsible for malaria breeding areas. It may be possible to have a certain proportion of bond issues for drainage work available for malaria control in connection with the major drainage projects. The time will come when the acceptance of railroad roadway construction will depend on the opinion of the State authorities as to whether proper drainage has been effected. It is estimated by Asst. Surg. Gen. H. R. Carter that 60 per cent of the malaria of the United States is man made. Obviously we may well direct our attention to the control of man's actions so far as they affect the general malaria problem.

G. H. Bishop, Assistant Sanitary Engineer.

Mr. Chairman, the necessity for exterminating mosquitoes and thereby preventing annoyance and unnecessary illness is coming to be recognized as an important function in many communities. Antimalarial operations are essential not only to the maintenance of good health but also to the establishment of sound economic conditions.

Evidence of the definite benefits conferred upon the people through proper malaria control are accumulating rapidly and especially since the Public Health Service has demonstrated what may be accomplished by appropriate measures in the several extra cantonment zones. The benefits derived from antimalarial operations are ex-

tensive and may be said to include (1) the individual property upon which the work is done, (2) the district or neighborhood, (3) the city or county, (4) the State. Consequently these persons or agencies should shoulder the financial burden in proportion to the benefits received.

Only during the past six years has malaria control work been carried on to any extent in the United States, and the bulk of this work has been done since April, 1917, in and around the cantonments. This work, being intended primarily for the protection of troops, was necessarily largely financed by the Government. However, persons residing in the vicinity of the cantonments likewise benefited through the extensive operations while governing officials of cities and counties were acquainted with the possibilities and uniform benefits to be derived from work of this character.

The continuation and further extension of this work will undoubtedly be demanded in many sections of the country. The question arises, Who shall carry on these operations? The Government can not assume any considerable share of the actual cost, as the work is of local benefit. Individual effort would avail practically nothing. Consequently the work must be done either by popular subscription or through the medium of corporations operating in certain areas. As these methods are not feasible, the important and far-reaching problem should, as soon as possible, be placed upon a sound financial and economical basis just as the public utilities, highways, agricultural drainage systems, or irrigation systems have been provided for and fostered.

Such recognition would necessarily originate with the State. By enacting the necessary legislation authority could be given cities, towns and counties to levy certain amounts or assess certain sums for the construction and maintenance of malarial control works. This law could cover in detail the legal procedure from the beginning to the completion of the work, together with provision for its maintenance. Methods of levying and collecting necessary taxes covering the required operations could likewise be set forth.

In order to assure its workability, such a law should provide a definite means of initiating action. This might be done by motion of a governing council, commission or board, by petition of property owners, or by a general election. It is also suggested that funds might be provided by definite mill levy on all property in the city or county, by the assessment of all costs against the benefited property or a combination of these methods. The method of paying for the maintenance of the control measures must likewise receive consideration.

It will probably be necessary, in determining upon an equitable method of distributing the cost of construction, to consider the

benefits accruing to the agricultural interests through the institution of drainage work. However, antimalarial work should be looked upon as a health measure benefiting the entire district and should be mainly financed and maintained as such, disregarding possible benefits to individual pieces of property.

A suggested method of procedure for financing antimalarial work is outlined below, the authority for the steps being delegated to the city and county commissioners through State legislation:

1. Upon motion of the city or county commissioners, or upon petition of 25 property owners, the commissioners will cause an investigation and report to be made concerning the extent and cost of the work to be undertaken, and establish the boundary of the district in which the work is to be performed.

2. Thirty days' notice should then be given by publication stating that it is proposed to begin and maintain the work in a certain area, the operation of which will cost an estimated amount and a certain sum for maintenance during the first year. Probably 25 per cent of this first cost and 25 per cent of the ditching work required by the maintenance should be assessed directly to the specially benefited property (i. e. benefited by drainage), and the balance should be raised by making a certain mill levy on all property in the district. The cost of oiling operation should be met by a stated mill levy on all property in the district and collected in the same manner as ordinary taxes.

Unless a majority of the affected property owners appear at an open meeting to be held for that purpose on a set date, and offer valid objections to the work, the improvements should be made and assessments levied as proposed.

3. The construction of the work by day labor or by contract should be ordered, all expenses being advanced from the general fund until the levy and the assessment is made. This assessment should include the entire cost of all preliminary construction and oiling work.

4. An assessment roll and schedule of property to be assessed should be prepared, likewise the levy for construction and oiling work.

5. During the last month of each year a levy and assessment for maintaining and oiling during the succeeding year should be prepared. This should be based upon the actual cost of the work already accomplished.

The money for this control work could also be raised by the State, by legalizing and authorizing city or county commissioners to include in their budget each year a certain amount which would not exceed an established mill levy on all property in a certain district under malarial control. This sum, which would necessarily be levied annu-

ally, should be in addition to all other taxes levied at the present time, but should not exceed the constitutional limitation of indebtedness.

New Jersey is believed to be the only State which has enacted legislation relative to mosquito control. However, if a standard law could be written and submitted to the States in the malarial belt it would undoubtedly prove popular. Provision for adequate funds, by placing malarial-control work on a permanent basis, would undoubtedly contribute greatly to the health and happiness of the people.

Discussion.

Dr. Carter. Mr. Bishop is right; only he is so right that he did not say enough. Much of the malaria in the United States is man-made. In places 50, 60, and 75 per cent. The offenders are the builders of lumber plants, owners of mill ponds, the railroads, county roads, and so on. Understand, I am not blaming them. They built ignorantly, but because they have done harm in the past is no reason why they should continue to do harm in the future. About five years ago at a meeting of the State health officers with the United States Public Health Service at Washington, I brought up the matter that no water should be allowed to be impounded in the various sections or any of the States where malaria prevails without a license from the State health officer making the requirements for this impounding. This is a law in Virginia, South Carolina, and I believe in Alabama. There should be a law in all the States governing such work. They do not make malaria conditions because they are unwilling to build in conformity with sanitary engineering. I am quite sure that 95 per cent would comply with our plans on request, but they do not know what they should do. It should be controlled, however, by law, and no railroad tracks, no public road as well as no ponds should be allowed to be finished save in conformity with the requirements of the health authorities. A bill has been passed by Congress this year appropriating $400,000,000 for public roads and highways. If used as it has been in the past I would say that every dollar spent in the malarious regions of the South and Southwest will do from 25 to 50 cents' worth of harm to health. This is unquestionably true.

Now, gentlemen, as to starting campaigns for antimalaria, be sure your campaign is properly planned. Choose the right place in which to make it. Let us make it where we can get the best return for your time. A prolonged and wide experience has shown me the advisability of starting a campaign in an industrial community. The reason is that the business man is ready to spend a dollar if he can get in return $1.50. Work on your industrial communities and then afterwards take the ordinary residence communities when they can see the benefits which have come to the industrial communities.

Mr. BISHOP. Mr. Chairman, I have just a few words to say in regard to methods to be used in financing malarial work. During the time we were at war the Government furnished most of the money, for the protection of military forces. The burden has not been upon us to any considerable extent to assist in raising these funds. For further work one of the most difficult problems of malaria control will be to provide the necessary funds. The accomplishment of this will be facilitated when malaria-control work is put on the same basis as the public utilities, highways, and irrigation. I think that we should use certain means now at hand to assist in obtaining these finances, or to reduce the cost of future control work by planning ahead. The point has been brought out here that it costs money to change work along the railway lines and highways and undo the harm that has been done during construction. We should look into the future to prevent the necessity of changing work that will be done this year. Millions are to be spent on highway work. Relocating railway lines, putting in concrete bridges to replace wooden structures, and building drainage ditches will cause needless expenditures in future years for control work if proper precautions are not taken now. There should be some person or committee to investigate these new improvements, finding out when and where the railroads intend to change their lines so that the malaria-control question can be taken up with them, and proper instructions given.

This is particularly true in territory where Anopheles mosquitoes breed, even if no immediate control work is contemplated. The railroads, of course, have objections to changing previously constructed work, but they can have no objection to building in conformity with plans that facilitate malaria control and cause them no inconveniences.

In dealing with railroads it is better to take the matter up at headquarters with the president, or chief engineer, getting their confidences and showing them what mosquito control stands for, than handling each situation locally with agents or superintendents.

Another need is laws enabling cities and counties to help finance malarial campaigns. At present, money to finance such a campaign is simply a question of donation. In order to establish malaria work on a sound basis in each city and each county where needed, the State legislatures should make laws setting aside a certain percentage of city, county, or State funds for general health or for malarial purposes only. Almost every State is contemplating highway work and will issue hundreds of thousands of dollars worth of bonds, and the Federal Government will aid to a great extent. Through this Government aid we should be able to exert some influence as to how this work is to be carried on with a view to eliminate the borrow pit, the

half-built drain ditch and culverts placed too high, each of which may produce mosquito-breeding places.

Mr. Van Hovenberg. Mr. Chairman, with respect to national legislation, the national malaria committee is available. It includes in its membership the majority of the men in the United States who are leaders in ridding this country of malaria. Mr. Le Prince is chairman of the committee on railroads. One of his ideas is that it may be possible, and certainly is advisable, to have a certain percentage of all authorized bond issues for drainage work set aside for sanitary control. In most instances in the South this would mean for malaria control.

(Upon adjournment at 9 o'clock p. m. the conference attended the motion picture show at the Bijou Theater to see the film Malaria Control.)

Morning Session, February 19, 1919.

Dr. Carter. The next subject on our program is "The use of dynamite in malaria-control operations." Mr. Base will open the subject.

THE USE OF DYNAMITE IN MALARIA-CONTROL OPERATIONS.

J. F. Base, Assistant Sanitary Engineer.

Control measures by the use of dynamite were carried on in the area just east of Camp Pike, Ark., along a stream known as Five Mile Creek.

This stream is the main outlet for the run-off from a narrow, hilly and wooded watershed. In addition it also carries the effluent from the camp sewage disposal plant.

The stream bed is interlaced rock and bowlders imbedded in clay. The average width was about 15 feet before control measures were begun. A growth of heavy brush was prevalent along its entire course. Due to this brush and the very rough bottom, the stream flow was very irregular, dividing into numerous small courses and standing pools over the entire width.

The condition formed was ideal for mosquito breeding, likewise very difficult to control.

Owing to the pollution of the stream (practically raw sewage owing to nonoperative plant), ditching and brushing operations by hand were impossible, owing to refusal of men to work therein. This, added to the nature of the material to be handled, prompted the decision to use dynamite as the main ditching agent.

METHODS OF PROCEDURE.

In the operation of working and loading holes, two laborers were employed, an experienced dynamite man supervising the work and firing the charges.

Holes were put down along the center line of a previously determined course at 2.5 to 3 feet intervals and to a depth of 1.5 to 2 feet. The holes were made with a heavy point bar, 5 feet long, forced down by thrust, one man being thus employed. Occasionally, in a very compact material, it became necessary to use a light sledge hammer to aid in bringing the holes to proper depth.

The second laborer followed immediately after the first, and placed the charges (previously primed by the dynamite man.)

The usual amount of explosive was one-half pound stick of 40 per cent strength Du Pont (Red Cross brand) dynamite, although this

was increased by one-half stick as conditions encountered, or desired results seemed to indicate. Waterproofed electric blasting caps were used for priming, the 6-foot length wires being preferred, thus permitting connection of alternate charges, eliminating use of connecting wire. Thirty holes thus connected were fired at once.

RESULTS.

The immediate results were satisfactory in confining the flow to a single central channel averaging 3 feet in width and 2 feet in depth, and removing roots, débris jams and heavy brush growth along the channel. A few minutes time was required to remove loose bowlders, brush, and débris which had fallen back into the channel.

Cost of work for 1,950 lineal feet of actual ditching covering a period of 10 days.

Cost of dynamite (415 pounds)	$100.64
Cost of exploders (668)	61.46
Cost of labor:	
Two men at $3 per 8-hour day (10 days)	60.00
One man at $5 per 8-hour day (8 days)	40.00
Total cost	262.10

Summary of cost:

Average cost per lineal foot of actual ditching	.134
Average cost per cubic yard of actual ditching	.607
Average cost per lineal foot of total stream controlled	.057

Bottom Land Muck, Underlain With Sand.

LOCATION OF WORK.

Dynamite was used in ditching operations along a large main stream known as Fourche Creek, at a point near its entrance into the Arkansas River, some distance east of the city of Little Rock.

CHARACTER OF STREAM.

This stream receives the runoff of an extensive area, and varies in width from 15 to 25 feet between banks. Nevertheless, during dry periods the flow diminishes to such an extent that broad standing pools and a small meandering stream is the result. To reduce the area of these pools and increase the flow in general, ditching was necessary. The consistency of the soil along the existing stream was difficult for hand excavation and expensive accordingly.

METHODS OF PROCEDURE.

Previous experience had demonstrated the fact that the use of dynamite in a soil of semiliquid consistency was not successful. For this reason, the idea of following the existing watercourse even in part, was abandoned.

A course was selected about 20 feet away from the existing stream, the soil being thoroughly dry (fissured about 18 inches deep), and the water level at the time being about 2 feet below the ground surface.

Holes for charges were easily and quickly put down with a shovel handle, at 3-foot intervals and 2.5 to 3 feet deep to the underlying sand strata.

In each hole, one-half to one pound of 40 per cent Du Pont (Red Cross brand) dynamite was placed, being careful to shovel each charge to the bottom of the hole. Being water-sealed no tamping was necessary.

The exploders were waterproofed. About 30 charges were fired at once.

RESULTS.

The immediate result was a ditch averaging about 3.5 feet in width and 2.5 feet in depth, with the excavated material thrown well back out of the ditch, except in several instances where heavy clods had rolled back into the channel or where the force of an occasional charge had been expended through the fissures, leaving a portion of the channel obstructed.

The cleaning out process after firing, however, was a small matter.

The final condition was a practically straight ditch in firm soil and of ample section for normal dry weather flow. The water level in this instance was lowered sufficiently to practically eliminate a large pool (several hundred feet long).

Cost of work for 400 feet of actual ditching.

Dynamite	$29.80
Exploders	10.67
Labor	10.50
Dynamite man	5.00
Total cost	55.97

Summary of cost:

Average cost per lineal foot of actual ditching	.14
Average cost per cubic yard of actual ditching	.43

Dr. CARTER. Mr. Allen will continue this subject.

A. F. ALLEN, SCIENTIFIC ASSISTANT.

Mr. Chairman, no unusual engineering features were encountered in the antimalaria work in the Camp Shelby zone, Mississippi, except

in the development of the use of dynamite for blowing drainage ditches through swamps too costly to drain by hand-dug ditches. In a large system of swamps to the south of Camp Shelby proper, it was found advisable to use dynamite because of the lower cost and the rapidity of this method of digging ditches as compared with hand-dug ditches, in the construction of main-drain channels.

In order to fully understand the reason for this use of dynamite, its necessity and the conditions under which it was used, it may be well to briefly describe the geographical, topographical and soil conditions surrounding Camp Shelby.

Camp Shelby proper is situated on a slightly rolling cut-over piney-woods tract. The soil is sand to a depth of at least 40 feet, practically unstratified, and with hardly an inch of top soil humus. This unstratified sand has no evident strata or pockets of gravel or clay and rapidly erodes once the top binding mat of grass roots is broken. The average elevation of the camp is about 280 feet above sea level. Three miles away to the north, Leaf River has an elevation of 110 feet. This fall of nearly 60 feet to the mile, combined with the rapid erosive property of the soil, gives rise to sharp V-shaped valleys, easily drainable on the north side of the camp. However, the topography on the south side of the camp is quite different. In this direction it is 10 miles in a straight line to the nearest stream of any size and the average fall, as determined by field instrument surveys, is about 10 feet to the mile. Erosion therefore being slower, the hills are rounded off and the slopes uniform, long and gentle, and the valleys are wider.

In the valleys the pine trees of the drier uplands are replaced by gums and bays with their characteristic hummocks of gnarled roots. Cypress is generally absent in these swamps. The gums and bays growing in the valley bottoms have, due to this peculiar type of root formation, caused so many obstructions to the flow of water through these wide, rather flat valleys that the water courses have become very tortuous and in many cases obliterated. The result is that during the rainy season the valleys are wide, slowly-moving sheets of water, with many channels flowing around these trees and knobs of roots. There has been a general, though slow deposition of organic muck in the valleys, giving rise because of its richness to dense swamp jungle growth.

The valleys in due course of time have become wide swamps, averaging a thousand feet, very irregular as to outline and practically level. The silting of organic muck has progressed to the extent that at places it is apparently 10 to 20 feet deep, and on top of this muck is a continuous cover of root mats of the gums and bays with occasional wide-spreading roots of solitary pines. In places the swamp was a quagmire, so that by jumping on a tussock one could

shake the entire area for 50 feet around it. Interspersed and intermingling all through the swamp are the climbing vines and reeds, making an almost impassable jungle. In the lower reaches of the swamp there appear semblances of channels very tortuous and oftentimes lost in the root jungles. It was necessary to dig some three miles of new main drain ditch through swamp of this character, and to open up, widen and straighten about two miles more of these extremely crooked channels. It is hoped that this description may show something of the difficult character of the swamp handled, and particularly of the root material encountered.

The figures quoted later on in this paper as to cost, apply to the new ditches dug through this swamp in those sections where there had been no previous water courses.

In the early part of the work in December, 1917, about a thousand feet of this main drain ditch, approximately 5 feet wide on the bottom, 4 feet deep, straight sided and level bottomed, was dug in this swamp prior to the arrival of the writer on the job. A small crew of men, about six to the foreman, was employed, two-thirds of them using axes, the rest potato rakes. Figures as to cost of the work at this time are not available, but it was averaging somewhere between 75 and 80 cents per linear foot of ditch. It was realized that this cost was altogether too high and it was suggested that dynamite be secured and a stick or two placed under the most difficult roots in advance of the digging gang. It should be borne in mind that at the time this work, and the work to be subsequently described, was being done, this entire swamp was wet, not only wet but in many places covered by sheets of water through which knobs of roots protruded. It was necessary first of all to brush a pathway some 10 feet wide through the swamp, and in this pathway to lay logs from hummock to hummock on which the men might walk. If they slipped off, they sank up to their waists in the water between the hummocks.

It was found that this method of occasionally using dynamite for breaking up the worst tangles of roots required less ax work than previously. The resulting broken-up roots could be pulled out of the ditch, using at that time ordinary potato hooks. This method of work reduced the unit cost per foot to about 60 cents. However, the size of the gangs employed was not materially increased. It was estimated that the use of more dynamite would further reduce this cost and the method of blowing ditches by exploding simultaneously a series of sticks of dynamite placed along the route of the ditch, all fired by an electric spark, was developed. There was nothing new in the method of procedure, it having been employed for several years for similar work. The method is well described in a little pamphlet published by the Institute of Makers of Explosives, 103 Park Avenue, New York City, entitled "The Use of Explosives in

Making Ditches," by J. R. Mattern. The only new feature of the work, at least so I am told by the demonstrator sent by the explosive company to inaugurate this work for us, is the extremely difficult nature of the swamp in which the work was done, the dense resisting root mat overlying the soupy muck.

For this reason it is necessary to describe at some length and in detail the steps taken when this method was developed to its most successful point. The pathway was cleared through the swamp approximately 10 feet wide, at a cost of from 4 to 5 cents per lineal foot of pathway. All big trees were cut some two or three feet above the ground, and the lower portions of the trunk that remained in the pathway after felling were cut and rolled to one side. Attempts were made to blow uncut standing trees bodily from the pathway, but the resistance of the branches was so great that they invariably fell back into the ditch, with the result that they had to be removed by hand at a cost much greater than that of originally cutting them and felling them so that they would be out of the way once and for all. Brush hooks cut away the vines, reeds, and thorn jungles. Small logs were laid from hummock to hummock to enable the dynamite crew to get about.

The dynamite crew consisted of a white foreman and four laborers; two of the laborers were employed in bringing the dynamite stored at the edge of the swamp up to the point of operations. One of the other laborers was provided with a pick handle with which he punched holes to the depth of approximatey 36 inches. These holes were in a straight line, as nearly as possible 18 inches apart. The other laborer dropped a stick of dynamite into each of these holes. Since the work was done during the months of January, February, and March, low-freezing nitroglycerin dynamite was used. We were told that the ammonia grades of dynamite would not explode by the method of propagation by shock. The foreman placed in each fifth hole an "exploder," this being a stick of dynamite into which had been inserted an electric blasting cap. Caps were used having 4-foot leading wires. Several different brands were tried, all of which worked successfuly. This "exploder" in each fifth hole was in addition to the stick already placed there by the negro laborer. After a series of holes for 100 or 150 feet had been charged, the wires from the various electric blasting caps were connected in series and a heavily insulated copper wire attached to the unconnected ends of the series. These heavy lead wires ran back into the swamp a distance of 200 feet to an electric battery box or magneto. These "battery boxes" are rated according to the number of exploders they are capable of exploding at one time. We used one capable of exploding 25 exploders at once, but found that it could not be worked uniformly successful on more than 20.

Various methods of placing the individual sticks of dynamite were tried, namely, in double rows 2 feet apart, which gave too wide a ditch; staggered at a distance of 18 inches from each other on 45° lines, which also gave too wide a ditch; and in a straight line 18 inches from each other, which was found to be satisfactory for our purposes. Various distances apart were tried, but 18 inches was found to be the best. More than that sometimes failed to explode the intermediate sticks even when fired under water, and often would result in a series of holes rather than a continuous ditch. When working, as was done, under water, there is no need of filling or tamping the holes. This permits very rapid work. Oftentimes the work progresses at the rate of 150 to 200 feet of blasting per hour, although this rate could be obtained only under particularly favorable conditions. Stumps occurring in the line of ditch required a few extra sticks of dynamite to tear them loose. The exact number of sticks required to remove a given size root can be determined only experimentally. It is better to waste an extra stick of dynamite, costing only 15 cents, than to have to use an hour's labor at 45 cents to chop loose and remove the undisturbed root. It was found that where this work was carried out under water that an exploder every 10 or 12 feet would fire all intermediary charges by percussion, although in some work on dry land it was necessary to use them every 5 feet. We were not able to explode a series from one exploder fired by the ordinary method of fuse and cap.

After the charge was fired the follow-up gang would immediately get into the work and pull out such large chunks of roots, root mats, and floating bunches of organic matter as had fallen back into the ditch. For this purpose potato hooks, and later large "phosphate drags" were used. Immediately following the explosion water would rush into the blown ditch from all directions and the resulting "soup" was extremely difficult to handle. In this work it was found that by keeping the completed ditch downstream in good condition, securing a fall at the head of the work at about 3 feet, that a force of men armed with potato rakes and a few axes could remove from the blown ditch all of the material which fell back or was washed back into it after a charge. And in addition, they continually maintained the ditch downstream free from trash and muck, which was continually being washed into it from the head of operations. The actual cost of the dynamite and the labor employed in firing was from 18 to 19 cents per linear foot of ditch. The labor required to clean out the ditch following a charge and to maintain the ditch downstream in good condition cost about 10 cents per foot, which, in addition to the original cost of about 5 cents for brushing the right of way, gave a total cost of about 32 cents per linear foot of ditch. This gives an irregular sectioned ditch with a minimum bot-

tom width of from 4 to 5 feet, and a depth below the general ground level, as nearly as it could be determined, of about 4 feet. Due to the uneven resistance of the material encountered, extreme variations in the width of the ditch resulted. At some places there was no lateral resistance at all, and the ditch was often a rather wide basin.

Throughout these swamps there were some deep natural pond holes and the ditch was usually run through as many of them as possible, in order to lower the water in them and to get a continuous flow through them, so that later on they could be oiled by dripping the main drainage stream. Hence, this main-drain ditch was rather crooked.

In the latter stage of the work a section of this same ditch, 3,000 feet long, was dug by hand for the purpose of again determining the cost of digging this ditch by hand without the use of much dynamite, but using somewhat larger gangs of men per foreman than previously. It was found that this section of ditch cost 42 cents per foot. It is evident, therefore, that the use of dynamite was very well justified in reducing the cost of the work.

This method of ditching is about six times as fast as handwork. Exclusive of the man days of labor required in brushing the right of way the total man days of labor required in the dynamite method was 3.9 man days per hundred foot of ditch, and for all hand-dug work was 11.2 man days per hundred feet of ditch; so that it is seen that there is an advantage in using dynamite when it is difficult to secure labor.

It was found that a ditch about 4 feet deep, lowering the water table about 3 feet, would draw laterally, so that 5 days after a rainy spell there was no standing water in the swamp 400 feet on either side of the ditch. Thus, a ditch through the center of the swamp would drain practically the entire width, although in some of the wider parts of the swamp toe ditches were required along the edges. These were always dug by hand.

It is somewhat doubtful if this method of dynamiting ditches would be economical, even under the difficult conditions described, for ditches less than $2\frac{1}{2}$ or 3 feet deep.

It should be remembered that dynamite is a very dangerous substance and due care should be taken against accidents. One minor accident, due to the unexplainable discharge of a blasting cap in the hand of a negro laborer resulted in his losing two fingers and the payment of several weeks' wages without a corresponding return in labor.

Unfortunately our experience in dry-land ditching is so limited that our figures have little value, but I believe that for the type of swamp described the method that we used is probably the most economical one that can be devised.

The attached table gives the following comparisons of cost in detail of the use of the dynamite method versus the hand-dug method: (1) The amount of labor in man days per hundred linear feet of ditch; (2) the amount of supervision in man days per hundred linear feet of ditch: (3) the number of half-pound sticks of dynamite required per hundred linear feet of ditch; (4) the number of electric blasting caps used in a hundred feet of ditch; (5) the number of days of wagon hire required to haul the dynamite used in blowing a hundred feet of ditch; (6) the man days of labor and man days of supervision required in the follow-up crew, or in the other case of the hand-dug ditch, of man days of labor, and the man days of supervision in the total excavation of a hundred linear feet of ditch. Also in the table are given the unit cost of these various items, and in another column the cost in dollars and cents for these various items per hundred linear feet of ditch.

In Public Health Reports for November 22, 1918, Mr. Hoskins has described this general method of ditching and has compared these same two methods on a basis of yardage removed and finds that the dynamite method is somewhat lower than the all-hand method.

I prefer not to use yardage as a basis of comparison, since in anti-malarial work the relative intrinsic value of two ditches is more often nearly proportional to their depths than to their cross-sectional areas. This is especially true in a dynamited ditch as compared with a hand-dug ditch, for the former must of necessity have wide sloping banks.

Therefore, in ditches of approximately the same bottom width, which is true of the ditch previously described in this paper, and of the two ditches which Mr. Hoskins describes, we can compare unit cost per linear foot of ditch after adjusting them to a common depth. Mr. Hoskin's ditch No. 60, which has a 4-foot bottom width and is 5 feet deep, cost, according to the figures in the report, 56 cents per linear foot of ditch. This ditch was dug with the aid of dynamite as generally described above. On the other hand, his ditch No. 62, 4 feet wide and 3 feet deep, cost, according to the figures in the report, 20 cents per linear foot. If this last cost is prorated to a depth of 5 feet the cost is 35 cents, which is only 60 per cent of the cost of the dynamited ditch.

In the absence of more definite information as to the nature of the work required of the two ditches, we can carry the discussion no further. It is evident that there are many factors entering into the discussion, in the absence of which we can not estimate the relative value of the two methods of work.

Extra-cantonment zone, Camp Shelby, Hatticsburg, Miss.

	Cost data of ditch dug with dynamite.			Cost data of ditch dug by hand labor.		
	Units of labor and explosives per 100 feet of ditch.	Unit costs of labor and explosives.	Costs per 100 feet of ditch.	Units of labor per 100 feet of ditch.	Unit costs of labor.	Costs per 100 feet of ditch.
Brushing crew:						
Supervision (man days)	$0.06	$7.00	$0.45	$0.06	$7.00	$0.45
Labor (man days)	1.15	3.25	3.75	1.15	3.25	3.75
Total cost			4.20			4.20
Dynamite crew:						
Supervision (man days)	.24	8.00	1.91			
Labor (man days)	.96	3.50	3.34			
Dynamite (sticks)	72.00	.17	12.24			
Caps (number)	5.40	.08	1.43			
Wagon hire (days)	.12	4.00	.48			
Total cost			18.40			
Digging crew:						
Supervision (man days)	.18	7.00	1.23	.46	7.00	3.22
Labor (man days)	2.55	3.25	8.27	10.70	3.25	34.92
Total cost			9.50			38.14
Grand total			32.10			42.34

Dr. Carter. I believe Mr. Harrub did a considerable amount of ditching with dynamite at Camp Johnston. We would like to hear from him.

C. N. Harrub, Sanitary Engineer.

The statements contained in this article on the use of dynamite in malaria control work are obtained from and based on the work done in the extra-cantonment zone Camp Joseph E. Johnston, Fla.

The zone in question was situated about 12 miles from Jacksonville, Fla., in low, flat country. Much of the area consisted of small swamps or depressions in which water stood for a considerable portion of the year. The larger of these never dried out. The depth of the water varied from about 6 inches to nearly 3 feet. The conditions were therefore favorable for the growth of cypress, and in all the larger swamps were growing cypress trees and the stumps of those which had been removed, together with dense growths of cypress knees. In some instances these knees were so thickly scattered that it was difficult to find footing between them. Such conditions rendered the use of shovels in opening ditches almost out of the question, but yielded to dynamite with absolutely no trouble.

METHOD OF PROCEDURE.

In wooded territory the first essential is to clear a right of way. It is not necessary to clear away all the small underbrush, but all

trees should be cut and removed beyond the limits of the ditch. This is to avoid having to handle them after the ditch is opened and to insure the removal of a larger percentage of the stumps beyond the edge of the ditch by the dynamite. The right of way on short ditches should be finished in entirety before dynamiting is started. This is to avoid loss of time on the part of the cutting gang by having to suspend work while a charge is being fired.

The next step is placing the dynamite. There are three things to consider in placing the charge—spacing of the sticks, depth to which they are placed, and the quantity of dynamite per hole. These all depend on the size of ditch required and the character of the ground. In wet, swampy ground free from large stumps a single line of holes spaced 18 to 24 inches apart, with 1 pound (two sticks) of dynamite to the hole, placed about 3 feet deep, will produce a ditch ranging from 8 to 12 feet wide and from 4 to 4½ feet deep. In hard, fine sand the holes should be spaced not over 15 inches apart if a continuous ditch is to be opened. If the sticks are too far apart a series of disconnected holes will result, and the charge may "cut off" when fired, leaving a portion of the line unexploded. It may also be necessary to place a double line of dynamite in order to procure the required width of ditch. Stumps may require from 10 to 15 pounds of dynamite, depending on the size.

After the dynamiting is finished considerable quantities of roots will be left sticking into the ditch from the bank. These should be cut off by a follow-up gang. This completes the ditch. It is not necessary to grade the bottom of the ditch to remove unevenness, as the flow of water will soon establish a grade. Of course, if in removing a stump from a ditch which dries out soon after storms a hole is produced which would hold water for any considerable time, such a hole should be refilled.

CHARACTER OF DITCH.

Dynamite gives a flat-bottomed ditch, U-shaped rather than V-shaped, the cross sections being more or less elliptical. Unless conditions are exceptionally bad the ditch produced is straight and clean, with good banks, except for the roots mentioned above. In certain instances sections of ditch were opened in which no further work was necessary after blasting.

COST OF WORK.

There are several factors which enter into the determination of the cost of ditching by dynamite. The accompanying diagram illustrates how the cost varies from day to day on the same ditch, due to differences in the character of the ground encountered. There are

several grades of dynamite which ranged from 23.5 to 33.75 cents per pound at the time this work was done. Ordinarily the cheaper grade will give satisfaction in swampy or mucky ground, but in certain conditions the higher priced or more sensitive grades will be found more economical. A total of 46,570 feet of ditch were excavated by dynamite at an average cost of 18.1 cents per foot. These ditches ranged from 8 feet wide by 3½ feet deep to 12 feet wide by 4½ feet deep. There were 51,150 cubic yards of material excavated at an average cost of 16.5 cents per cubic yard. These figures include costs of labor and material, cost of transportation of labor and material, and supervision. They do not include clearing right of way nor cleaning out roots after dynamiting. These items would increase the average cost to about 27.5 cents per foot and 25.1 cents per cubic yard. Most of the work was done at a cost below this average, and if we had known at the start what we later found out, the average cost would have been less.

Referring to the diagrams it will be seen that on ditch D, the unit cost was considerably higher than on the others. There are several reasons for this; first, that was one of the first ditches blasted, and as we then had no storage facilities near the work, we were obliged to haul the dynamite from the magazine at Jacksonville, about 15 miles away. Later we built a magazine on the ground and saved about an hour a day on hauling. Second, we were using the high-priced dynamite, and third, on the earlier ditches a cap was used in each hole and all were connected together and then to the battery for discharging. That is, if we had 100 holes we would use 100 caps. This not only increased the cost for material but also for labor on a given length of ditch, for it took quite a little time to put in the caps and wire all the holes together. Later a cap was placed only in the hole at one end of the line as it was found that the whole line could be exploded from a single hole. This appreciably reduced the cost of the work.

ADVANTAGES AND DISADVANTAGES.

There are three types of ground in which the use of dynamite was found especially advantageous, namely, old steam beds and other soft mucky ground which afforded no footing for the laborer on hand work, areas containing large stumps, and areas overgrown with palmettos or cypress knees.

Probably the one greatest advantage in using dynamite is the saving in time. One man with two helpers will open as much ditch in a day as 125 to 150 laborers with shovels, even in good shoveling.

No disadvantages were apparent on the work in question.

COMPARISON OF COST WITH THAT OF HAND EXCAVATION.

No fair comparison of the costs of hand excavation and dynamite excavation can be given because both methods were not used on any one ditch, nor even on ditches of the same size on similar ground, and because the dynamite work was confined to areas in which hand excavation would have been extremely costly and in some instances absolutely impossible. The best comparison that can be made is between hand-dug ditches in high, firm ground and dynamite ditches in low, boggy ground.

Diagram Z shows the costs of such a hand-dug ditch averaging 13 feet wide by 7 feet deep. Allowing for the difference in cross sectional area of the two ditches the cost per linear foot of hand-dug ditch, and the cost per cubic yard of material excavated are approximately 2⅓ times the corresponding unit costs of the dynamite ditch. This, however, does not indicate that ditch Z could have been dug cheaper with dynamite. The ground was compact, clayey soil, and in order to open a ditch of this size with dynamite it would have required a double line of dynamite, and possibly following the first shot, a second single line in the bottom to secure the required depth. This would make the cost equal or exceed that of hand labor.

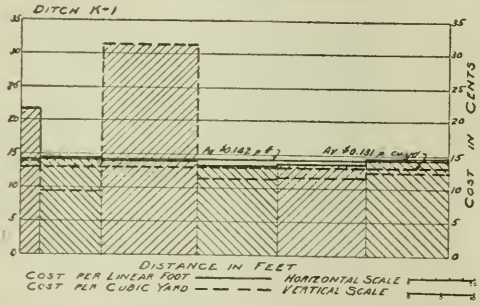

FIG. 20.—Diagram showing cost of ditch excavated by dynamite.

Comparisons of this kind are misleading and are really of little value in determining the relative advantages of the two methods of excavation. No hard and fast rules can be laid down for deciding when one method shall or shall not be used. A little common sense and experience after studying the conditions on the ground are the best guides in determining which method to use in any given case.

If dynamite is to be used in any considerable quantities, the services of an experienced dynamiter should be secured. It will be necessary to pay him a higher wage than for ordinary labor, but a good man, by more advantageous use of his material, will prove the cheaper in the final analysis.

EXPLANATION OF DIAGRAMS.

Diagram D, K–1, N, O, represent the cost of ditches excavated by the use of dynamite; diagram Z that of a hand-dug ditch. Diagram A shows the manner of placing the dynamite, also the method of

attaching the exploder to the stick of dynamite. After the first preliminary work only one exploder was used with a line of dynamite. This diagram also shows the average size of ditch obtained by a single line of dynamite.

The horizontal distances represent linear feet of ditch opened, the distance between any two vertical lines representing the distance covered in a single day. The vertical distances represent the cost of the work as explained in detail on the diagram.

Dr. Carter. Mr. Hoskins will please tell us something of his experience in ditching with dynamite.

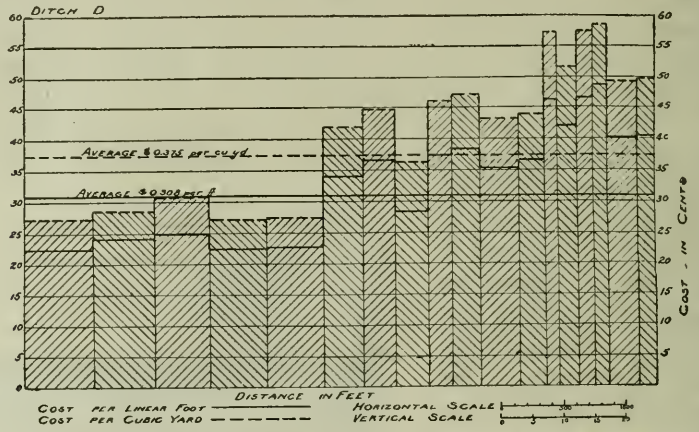

Fig. 21.—Diagram showing cost of ditch excavated by dynamite.

J. K. Hoskins, Sanitary Engineer.

That dynamite may profitably be used for excavating in swampy, mucky soils, was demonstrated in the course of United States Public Health Service antimalarial drainage operations in the extracantonment zone at Camp Wheeler, Ga., last year.

It was found that, in such areas, ditching could be done 6 cents per cubic yard cheaper by the use of dynamite than by hand labor, with wages at $3 per day and the working day 10 hours. The time and labor saved by the use of dynamite for this work are also, it is believed, important factors.

The economies in each of these directions are shown in the following figures, covering the construction of two ditches, one excavated by the use of dynamite, and the other by hand labor:

	Ditch dug by dynamite.	Ditch dug by hand labor.
Cubic yards	4,151	1,596
Average depth of ditch in feet	5	3
Average width of ditch in feet	8	4
Labor cost	$308.90	$671.75
Cost of material	$1,265.10	$38.75
Total cost of excavation	$1,574	$710.50
Cost per cubic yard	$0.39	$0.45
Man days at $3	$133	$124
Man days per cubic yard	0.024	0.140
Cubic yards per man day	41.66	7.14

The cost of excavation in the case of the first ditch included cleaning out the ditch after it was dynamited. In the case of the second ditch, the cost of excavation includes the cost of a small quantity of

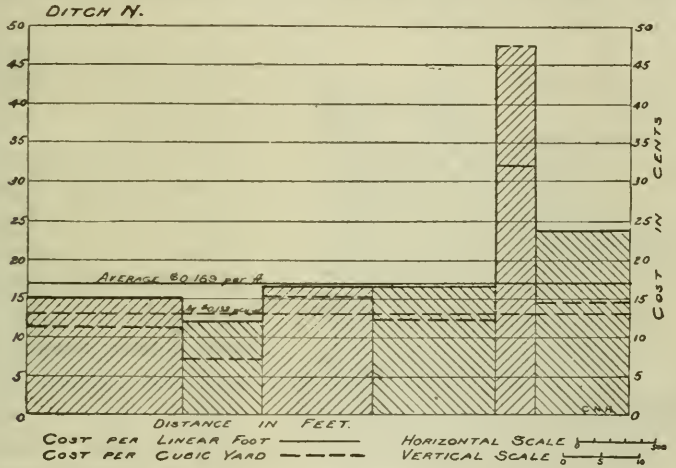

FIG. 22.—Cost of ditch excavated by dynamite.

dynamite used to facilitate removal of large stumps. In neither ditch is the cost of the preliminary clearing included.

It is probable that the cost of excavating the first ditch by hand would have greatly exceeded 45 cents a cubic yard, owing to the very difficult nature of the soil—a mass of yielding mud, largely under water, in which it was almost impossible to work.

The method of using the dynamite was as follows: After the surface had been cleared, dynamite was planted in two rows of holes, the rows being about 2 feet apart. The holes were from 3 to 4 feet deep and from 1½ to 2 feet apart in the rows. These holes are usually made with a shovel handle or round stick. One stick, ordinarily, was placed in a hole. In cases, however, where there were large adjacent stumps or logs, two or more sticks were placed in a hole.

A detonating cap and fuse were then attached to a stick in a hole near the middle of the section planted. The concussion resulting

from the explosion of this stick was sufficient, owing to the water-soaked nature of the soil to set off all the other sticks in the section.

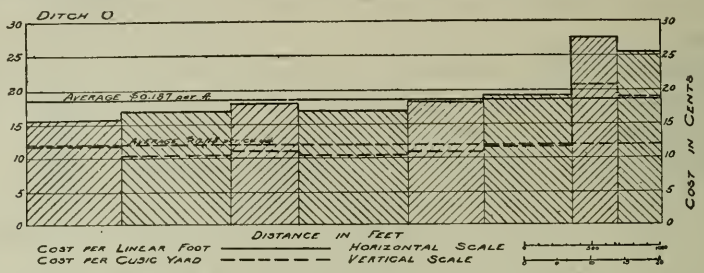

FIG. 23.—Cost of ditch excavated by dynamite.

Such an explosion would create a ditch from 6 to 12 feet wide and 4 to 8 feet deep, depending on the soil and the skill of the blaster. The sections exploded in this way ran in length up to 150 feet.

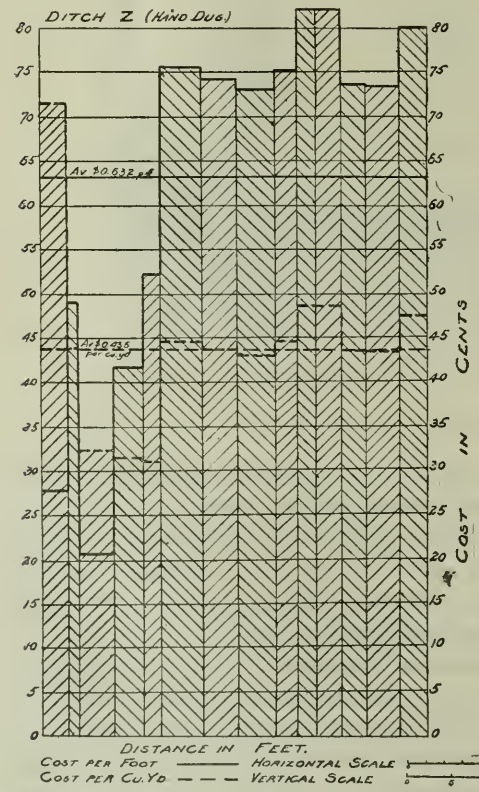

FIG. 24.—Diagram showing cost of hand-dug ditch.

The only men employed in blasting the ditch here referred to were two negro dynamite men and a couple of laborers who carried the material to them. After the blasting was finished and the section had had time to dry out—usually a few days—a small gang was put to work removing the débris and raking out loose mud and occasional ridges left in the bed of the ditch.

The method above described for use in wet, swampy areas does not work satisfactorily in dry ground, since it is necessary that the earth be water soaked in order that the concussion may be widespread and severe enough to explode the charges in the other holes. Straight 40 per cent or 60 per cent dynamite must be used and should be exploded as soon as loaded to prevent chilling of the nitroglycerin.

It was found that in cases where a smaller ditch was desired, a single row of holes generally sufficed. For deep ditches in difficult ground it may be necessary to use more sticks to a hole. Experiment is necessary to determine the amount of dynamite required for the soil through which it is desired that the ditches be excavated.

It was found that in timbered or brush-covered swamps it is advisable to first remove the timber or brush, but not the stumps or roots. Stumps are best removed at the time the ditch is exploded, since, if removed first, the continuity of concussion is broken by the stump holes left. Trees and brush are likely to fall back in the ditch after the explosion and become difficult and expensive to handle.

Another similar use to which dynamite was put in the Camp Wheeler extra-cantonment zone work was the straightening and

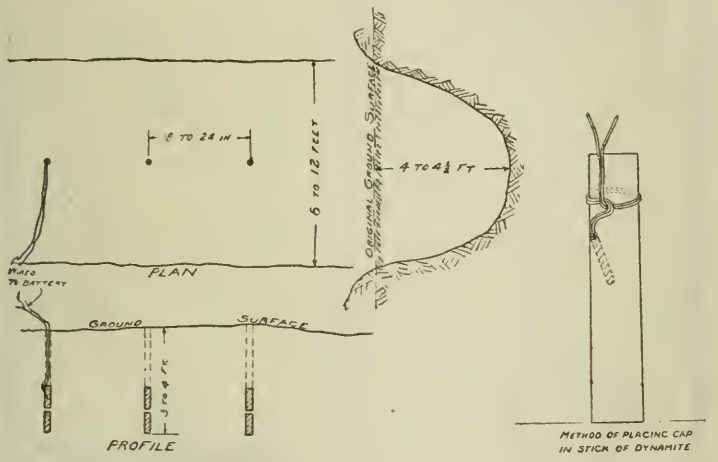

DIAGRAM SHOWING DYNAMITE SPACING & DITCH SECTION.

FIG. 25.

deepening of creek channels. An instance of this sort of work was the improvement of Swift Creek. This stream, which averaged about 20 feet wide, had an extremely tortuous course, which gave rise to pools and backwater, very objectionable from a malaria standpoint. The depth of the stream varied from 1 foot to 6 feet. A hard sand stratum underlying the soft ooze at a depth of about 6 feet made an ideal base for reaction of the explosion and enabled the upper soft layer to be completely removed, stumps included.

The following table shows the costs of the work:

Length of creek in feet	4,540
Labor cost of dynamiting	$123.75
Cost of material	$1,260.10
Labor cost of subsequent cleaning of channel	$132.50
Total cost of work	$1,516.36
Cost per linear foot	$0.334

It is believed this figure is considerably below what a similar job by hand labor would have cost. The creek bed in spots was too soft to support a man; in others, the water was too deep to permit satisfactory work.

Dynamite also was used with considerable economy of time, labor, and money in the removal of large stumps and logs encountered in

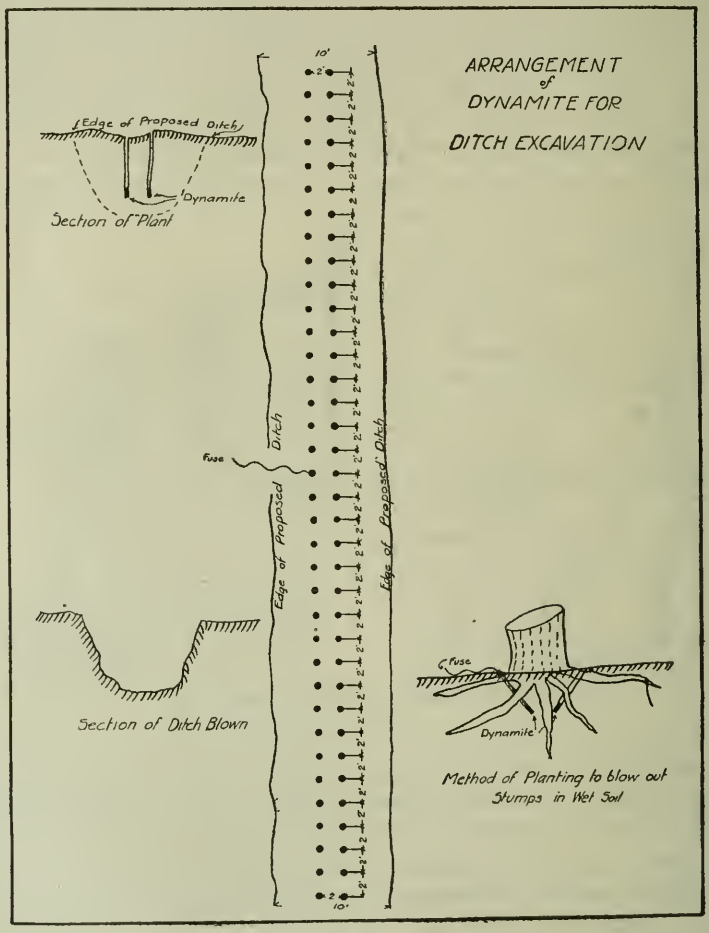

FIG. 26.

the course of ordinary ditching. Frequently in such work huge stumps were met with which would have defied the efforts of the laborers for hours. In such cases two or three sticks of dynamite were inserted under the stump, and in a few minutes the obstruction had disappeared.

When such obstacles were encountered in water-soaked ground the dynamite was exploded by means of a detonating cap and fuse at-

tached to one of the sticks. If, however, the ground was dry, an ordinary blasting battery was employed, the wires being connected, of course, to each charge.

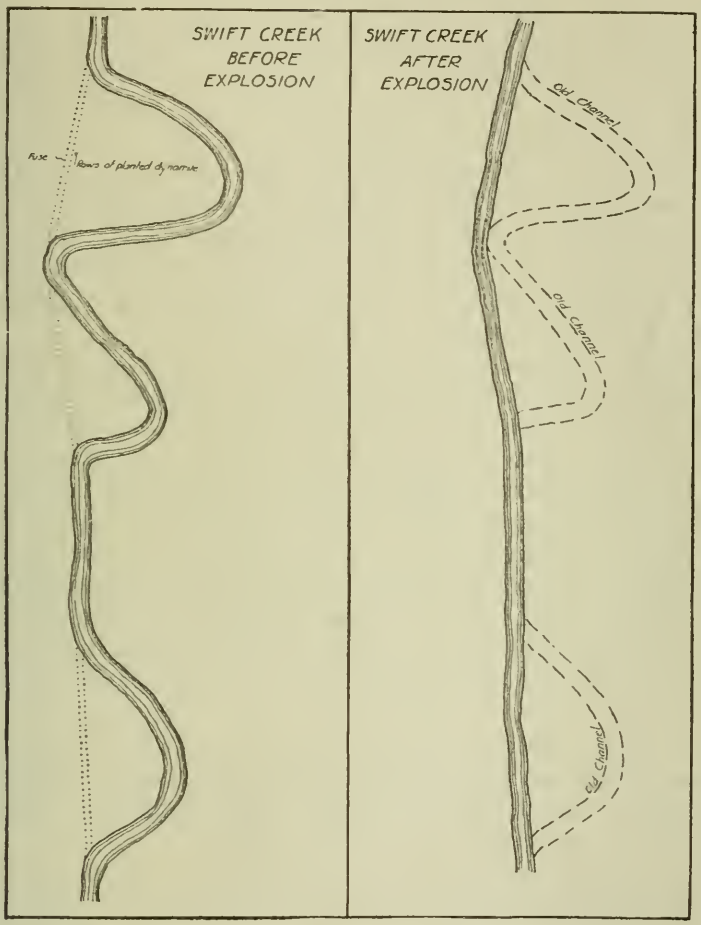

FIG. 27.—Diagram of Swift Creek before and after explosion.

It is believed that the economy achieved by the use of dynamite in the manner indicated is very much in excess of any reasonable risk charge that may be adopted.

It should be emphasized that the use of dynamite is recommended for excavation work only in the soils and under the conditions indicated.

Dr. CARTER. Mr. Tiedeman has also had some experience with dynamite. We would like to hear from him.

W. D. Tiedeman, Assistant Sanitary Engineer.

Mr. Chairman, the swamps encountered at Americus were quite characteristic in the thickness of the growth of trees, the profuse almost tropical undergrowth, and soft, boggy ground. These features, together with the fact that the ground was often covered with water, made ditching difficult. On several occasions teams of mules were hired and an attempt made at ditching by machine where the ground seemed firm, but the mules either bogged up and were helpless or the roots were so thick that by the time they were removed there was little work left for the ditching machine. Difficulties were also encountered in trying to dig these ditches by hand. In the warm weather some of the laborers were willing to go into the muck up to their waists, but could not work to advantage, and it seemed that as much soil flowed back as they removed.

Ditching by the use of dynamite has been by far the most successful under these circumstances. Nine tons of dynamite have been used in this way at Americus. In general the process consists in placing a row of sticks of dynamite at short intervals at a uniform depth below the ground for a considerable distance along the line in which it is desired to open a ditch. The simultaneous explosion of these sticks will throw the soil about 150 feet in the air and scatter it from 100 to 200 feet on each side of the ditch, leaving an open ditch from 2 to 6 feet deep and 3 to 10 feet wide, depending upon the charge, depth, and spacing. Stumps can be removed at the same time the ditch is opened by placing a little heavier charge of dynamite near them.

There are two methods of firing charges, by electricity and by cap and fuse. With the electric battery the charge may be exploded by propagation or by continuous wiring. The cap-and-fuse method is of use only when conditions favor propagation.

The propagated method can only be used in wet ground and where the temperature of air and water are at least 50° F. In this method the sticks of dynamite, which must be of high grade, at least 40 per cent straight nitroglycerin, are spaced not more than 24 inches apart in the line.

All the dynamite in the line is exploded by concussion from the single cap. This method is a time saver and the increased cost of the dynamite is counterbalanced to some extent by the saving in caps and is more than equaled when the saving in time is taken into consideration. As was previously stated this method is not effective in dry ground, but it was used exclusively in Americus, as dry ground is an unknown quantity there. In passing it might be stated that both 50 and 60 per cent straight nitroglycerin dynamite have been used in this work. The 60 per cent dynamite costs about $40 per

ton more and as far as could be determined gave no better results than the 50 per cent dynamite.

In detail, ditching with dynamite was practiced in Americus as follows: The trees were cut along the line it was desired to run the ditch, a wide enough space being cleared to allow for the width of the ditch and good paths along the sides. Holes were made for the dynamite; a bar made up of a piece of 1¼-inch pipe 8 feet long with a piece of 1½-inch pointed round steel welded in one end of it was used to make these holes. Under all conditions encountered at Americus two men lifting and dropping this bar could readily make a hole large enough to drop a stick of dynamite in. Two men could make and charge on an average about 12 holes 4 feet deep in an hour. The work was started at the outlet end of the ditch.

Assume that a ditch about 5 feet deep, 8 feet wide at the top, and 2 feet wide at the bottom was desired. The holes would be sunk about 4 feet deep and about 15 inches apart along the center line of the ditch. Each hole would be loaded with one and one-half sticks (three-fourths pound) of dynamite as soon as the bar was withdrawn; otherwise the hole might refill before loaded. The dynamite would be pushed down to the right depth by means of a stick with the depth marked on it. No tamping would be necessary where the water covers the stick. Extra charges of dynamite should be placed near and under stumps. Care should be taken to keep these sticks close enough together to fire by concussion. It was found cheaper to use sufficient dynamite to remove the stumps at the first shot than to try to redynamite them or cut and pull them. When the holes have been sunk for a distance of from 30 to 100 feet along the line, an extra stick of dynamite primed with cap and two or three minute fuse would be placed in a hole near the center of the line and an extra stick unprimed placed in each of the adjoining holes. Some people seal the joint between the cap and fuse where the charge is to be fired under water, but this was not found necessary. The fuse can then be lit and the whole charge fired by concussion.

It was generally necessary to make trial shots before the correct loading could be determined, but it was found an easy matter to open any sort of a ditch desired. In some cases the dynamite was broken up into quarter sticks spaced a foot apart and a foot and a half deep and a ditch about 2 feet wide and 2 feet deep opened up. It was generally necessary to do some pulling out of roots and a very little digging by hand in order to place these ditches in good condition.

The only limitation to ditching by dynamite that developed in the work at Americus was that it could not be used close to a railroad trestle. No particular difficulties were observed in the use of dynamite for ditching.

It is difficult to draw a fair comparison between the cost of the digging a certain ditch by dynamite and the cost of the same ditch by hand labor. All of the most difficult and deepest ditches in the Americus work were opened with dynamite, while the fairly accessible and light work was done by hand digging. In one section, which offers the best comparison, 3.3 miles of ditches were opened by dynamite at a total cost of $645 per mile, while 4.3 miles of ditching were done with pick and shovel at a cost of $715 per mile. When it was taken into consideration that a part of the hand ditching was merely the deepening from 6 to 12 inches of old ditches, probably averaging 18 inches wide, whereas the ditches opened by dynamite were of good size, and, though difficult, ground ditching by dynamite is by far the cheaper.

Ditching by dynamite under Americus conditions seems to have everything in its favor, that is, (1) it is possible to dig a ditch through land filled with roots and stumps, removing the stumps at the same time the ditch is opened; (2) it is possible to open a ditch in ground that is too boggy to be shoveled; (3) there are no large spoil banks along the line of the ditch as the dirt is scattered broadcast; (4) a ditch of almost any size desired may be opened; (5) the work is done very quickly; (6) little labor is required, which is a big item in these times; (7) the work is more agreeable to laborers and they can be held longer; and (8) the cost is much less than handwork.

Discussion.

Dr. Williams. Mr. Chairman, my experience in the use of dynamite in antimalaria drainage was entirely confined to the loosening of log jams and removal of stumps from stream beds and banks.

The largest creek near Millington, Tenn., (Big Creek) was choked with log jams. These ranged in size from 20 to 30 logs up to many thousand. One jam, the largest, was about 50 feet wide, 10 feet deep, and extended up stream about 100 yards. In the area of control there were about 50 jams of considerable size. Their removal was necessary.

This creek was subject to frequent overflow. Such time as an overflow receded and the water retired from the surrounding country and left the banks passable, yet with a full head of water in the stream, was selected as the best to use dynamite. At this time a log jam was under its greatest water pressure and yet approachable.

The method was simple. The dynamiter crawled out on the jam at its down stream end. Two, three or four bundles of dynamite (20 pounds each) were lowered down in the face of the jam—or placed between the logs near the jam face—and later exploded by

electricity. When done in this manner the entire jam is subject to a considerable shaking-up. The logs that had first caught and started the jam were loosened and the majority of the jam started down stream, moved by the water above. The banks were lined below by laborers with poles, who prevented new jam formations, and thousands of logs were floated far below the area of operations. This saved much money, as the remaining logs must be removed and piled by mule power, at an average cost of 50 cents per log.

These jams were mainly started by the catching of logs against the numerous stumps and trees that were found in the stream bed and on the banks. To prevent future jam formation, these, too, had to be removed. Dynamite was again used.

In these operations an expert dynamiter is most essential. An inexperienced man or one with little judgment wastes dynamite and time, both expensive commodities. An expert saves dynamite by his knowledge of the variation in trees as regards their roots as well as his knowledge of placing a charge and the quantities thereof.

There were encountered two classes of trees—those with a large tap root and small laterals, and those with no tap root and large laterals. In a tap-rooted tree it is best to bore one or more holes in the tap root and insert one-half to 1 pound of explosive. Then ring the tree with 2 or 3 pounds (depending on size of tree) and detonate by electricity. The charge in the tap root cuts it and the whole charge lifts the stump. The stump with no tap root and large laterals are not so simple. The greatest offender among these was the sycamore, and there were a great many of these near Millington. A charge beneath the stump's center yielded a riven stump with each piece attached to a separate root—worse than before. Prospecting with a crowbar disclosed the location of each root. Each root of over 4 inches diameter was bored near the stump and an eighth to a quarter pound of dynamite inserted. A small lifting charge was placed beneath the stump and the whole electrically detonated. The root charges cut each root and these with the center charge lifted the stump.

In this fashion nearly 6,000 stumps ranging in size from a foot diameter to 5 feet were removed. The average cost per stump was $1.36. Average amount of dynamite per stump was 4 pounds.

A word as to electrical blasting machines. We used nothing but ordinary commercial telephone dry cells of the type of Columbia Ignitor, at 20 cents each. Six connected in series will detonate seven charges. They are conveniently carried in a small box. If it is desired to detonate more charges, then add more cells. These are cheap, easy to handle, never get out of order, and are very effective.

Cost data.

Foreman, per day	$5.00
Laborer, per day	2.50
Wagon and horse, per day	3.00
Electric fuses per 100	6.30
Dynamite, per 100 pounds	23.50

Mr. CLARK. Mr. Chairman, the field equipment for blasting ditches is: Dynamite, electric fuses, blasting machine, lead wire, connecting wire, punch bar, and tamping stick. The procedure is as follows: All men are put to work priming the cartridges with electric fuses. The blasting machine is set at a convenient place, preferably in sight of the rest of the force, the length of the lead wires, or about 250 feet distant from the charge. One dependable man must be left in charge of this machine and explicit instructions given for the operation of it. The second man carries dynamite; the third punches holes and places the charges; the fourth connects up and tamps, when necessary. Not more than is needed for one day's work should be taken into the field at one time. Dynamite should be stored in dry, well-venilated buildings located in isolated places, if possible, or where it can be kept under close surveillance.

BLASTING STUMPS.

It is always advisable to blast stumps which are within the limits of the ditch. Heavy charges are placed directly under the main body of the stump and lighter charges under the heavy roots. From three to five sticks will completely remove a 12-inch stump, charge depending upon the character of growth and nature of soil. The stump may be shattered by placing the charges shallow and close to the stump, but this requires a great deal of root cutting.

DRY SOIL.

Placing dynamite in dry soil requires more time than in wet soil because it is necessary to tamp the charges, or in retentive soil a quicker way is to fill the holes with water, which method is just as effective. Dynamite is not as effective in loose sandy soil as in wet or plastered soil because the greater pore spaces allow the gases to dissipate their force without much resistance.

WET SOIL.

Wet or heavy soils require less dynamite to do the same work, and less time in loading. The size of charge should be increased, or placed closer together where roots are encountered. Stumps in the ditch path should be loaded in proportion to their size and connected in

the same circuit. Forty per cent dynamite will give good results when placed 2 to 3 feet apart with one stick (half pound) in each hole, about 2 feet deep. This loading in heavy soil will blast a ditch about 6 feet wide and 3 feet deep. In using 20 per cent dynamite charges should be placed 18 inches apart in light soil. All the classes require more or less hand labor to cut overhanging roots and to finish up in general.

MARSH.

Ditch blasting in marshes is very satisfactory from every point of view. No tamping is required; places where men are unable to work on account of sinking knee deep, or deeper in muck or silt, places where the roots of cattails, reeds or sedges and the like are matted into a tough mass can be blasted and a finished ditch obtained by the proper use of dynamite. Experiments show that deep loading is entirely unsatisfactory, also that slow-acting, low per cent dynamite is practically worthless. The reason for both failures is that the soft soil offers very little resistance. However, if these same charges are placed within the roots, or possibly at the lower edge, never under, the result will be an almost perfect ditch. A perfect ditch in a salt marsh would not be so classed were it a gravity ditch. Ragged edges and uneven grade through a tidal marsh are not objectionable provided the higher points are at or below the desired grade. In salt marsh ditching done at Newport News the results were surprisingly in keeping with proper ditch specifications; a 2-foot berm was left almost in as good shape as if the ditching had been done by hand. The blast seemed to split the turf at the center, raise it possibly 10 feet, turning it completely over and placing it to each side, according to specifications. The ditch referred to above is 7 feet at top, 4 feet at bottom, and 3 feet deep. Effective marsh blasting can be done all winter.

So far no blasting experiments have been made in frozen marshes; but it is believed that the best results could be had, were it done with the ground in a frozen state because of the fact that it would offer more resistance, and this is what is needed. The handling of dynamite during freezing weather is, of course, an obstacle to overcome, but nevertheless it is expected that the results obtained will offset this cost.

PROPAGATION METHOD.

The propagation method of blasting has not been tested to any extent here. Its failure in limited experiments, as well as the recent increased cost in the more sensitive dynamites, has discouraged the use of this method.

CONCLUSIONS.

In conclusion: Dynamite may be used most advantageously in salt marsh ditching; for stump removal; for removal of matted roots in light swamp soils; and for complete ditching in heavy swamp soil. Machinery or hand labor can be used to a better advantage in dry soil for the construction of small ditches.

When time is an important factor, and labor is difficult to obtain, the use of dynamite is especially advantageous.

Mr. PHELPS. Mr. Chairman, there is one thing that I would like to bring out; that is the possibility of using both the 40 per cent and the 60 per cent dynamite at the same time. The 40 per cent can be used under stumps with exploders, and the 60 per cent exploded by propagation from it, thus removing stumps and excavating the ditch simultaneously. The great advantage of dynamite to my mind is the saving in time and labor. By its use we were enabled to finish the Blackwater Swamp ditch before the winter rains set in, when it would have been impossible to have obtained the labor to finish it by hand within the same period.

Mr. HOSKINS. Mr. Chairman, replying to the question of Mr. Allen regarding the digging of small ditches with dynamite, we found that we could put in a small ditch with dynamite more economically than we could by hand, say ditches 3 feet wide and 2½ feet deep.

In using dynamite in ditching, if it is possible to use cap and fuse you will find that time will be saved by using the propagation method. All of our work was done during the summer months, from May to August, and we had no trouble with nonexplosion due to chilling of the nitroglycerin.

The cost of dynamite as compared with digging cost, I do not think we can state very accurately just now. The cost of our work per linear foot averaged around 33 cents for the dynamite work and about 45 cents for hand labor. The cost per cubic yard on one ditch was 39 cents by dynamite and 45 cents for hand labor. However, there were many places where we could not use hand labor on account of the sloppy consistency of the soil and consequent prohibitive cost of this method.

We also used dynamite in straightening stream channels to great advantage both in point of time and cost.

Mr. SPAULDING. Mr. Chairman, one of the problems that we had to face at Columbia was Percival Pond. This was an old mill pond, of which there are many in Richland County, S. C. Few of these ponds are being used, and yet the history of malaria cases reported through the laboratory last year indicated that they are the chief offenders in this community from a malaria standpoint.

This pond was within flight distance of the base hospital at Camp Jackson. It was about 2,000 feet long and averaged 300 feet in width. More than half of the pond was a tangled swamp and the backwaters formed ideal mosquito breeding places between the roots of the swamp gums. It was inspected by Dr. Carter and Mr. Le Prince in 1917, and they agreed that complete drainage was necessary. We tore out the spill way but that was not sufficient, so we knocked out the concrete base of the spill way and went down three feet, but that was not enough. The trouble was that the old stream bed meandered a very devious course through the valley, which was comparatively flat, so that a straight channel was necessary to get the water out of the upper end. It looked like an ideal situation for dynamite, and after a few experimental shots by the demonstrator, the dynamite method was adopted.

We blew a ditch 2,000 feet long, using the propagating method. The average length blasted at one time was 200 feet. Charges were placed in a single line of holes 18 inches apart and 3 feet deep. Two sticks of 60 per cent straight nitroglycerin dynamite in each hole or two-thirds of a pound per foot were required to give a ditch 5 feet deep and 10 feet wide at the top, when the going was good. However, extra charges under stumps, logs and hard places brought the average up to eight-tenths pound per foot. The dynamite cost 33 cents per pound. The total cost including labor and supervision was 28½ cents per linear foot, and the same per cubic yard.

In addition to this main channel dynamite was used on 1,000-foot side channel which served to intercept a small stream which formerly entered the upper end of the swamp. It also collected seepage. This was very rough work. The ground was interlaced with roots and although saturated with water was comparatively firm. Five hundred pounds of 60 per cent straight dynamite were used to produce a ditch 3 feet deep, 6 feet wide at the top, and 1,000 feet in length. In this case the cross section of the ditch was a perfect V. The total cost per linear foot was 19 cents, and per cubic yard 57 cents.

The ditches thus provided, together with a short length of seepage ditch of small size dug by hand, drained the pond very satisfactorily. A few deep holes in the old stream channel were cared for by oiling.

Dr. Carter. Our next subject is "Larvicides." Mr. Hardenburg will please open the subject.

LARVICIDES.

W. E. Hardenburg, Assistant Sanitary Engineer.

Mr. Chairman, creosote was tested for a few weeks in the Camp Wheeler extra-cantonment zone in the fall of 1918. On the whole, it was found very satisfactory.

In the first place creosote is much more economical than ordinary mosquito oil; while its cost is perhaps twice that of the oil, 1 gallon of it will do the work of 5 or 6 gallons of oil. This fact also indicates that considerable saving in transportation and distribution of the lethal fluid is possible when creosote is employed.

It was found that creosote was particularly useful in protecting the edges of streams and ponds and in places where the heavy verdure would interfere with oil spraying. One defect noticed, however, was that the mist could not be shot more than 5 or 6 feet, while oil can be discharged 30 or 40 feet when necessary.

Creosote as a rule killed both larvæ and pupæ in from 15 to 20 minutes. On one occasion a couple of frogs were hit by a discharge while in an inclosed pool, and died in a short time. This would seem to indicate that fish in a similarly inclosed pool might also be killed. However, no damage to fish was noted in running streams from 3 to 10 feet wide, on which most of the tests were carried out.

A 4-gallon automatic type of insectide sprayer was used. It cost $6, but was not entirely satisfactory on account of its awkward shape.

Discussion.

Mr. Tarbett. Mr. Chairman, during the past year I have used niter cake very effectively in dosing fire barrels. Each barrel was dosed with approximately 3 pounds of the cake, which was added dry without any attempt at pulverizing or making a solution. One thousand two hundred to 1,500 barrels were dosed, and no breeding occurred in any of these throughout the season.

Experiments showed that a solution of niter cake added in the proportion of 1 pound of dry cake to 50 gallons of water killed the larvæ in 15 to 20 minutes, but did not affect the pupæ. As the niter cake cost us nothing the simple method of adding an overdose of the dry salt to each barrel was tried and, as stated before, with very good results.

As to breeding in catch basins, I had intended trying niter cake added in fairly large quantities. However, due to the very dry season, we had little occasion to try this out. In one instance, however, in a small catch basin about 10 pounds of the dry cake were added and no further breeding took place.

Mr. Le Prince. Mr. Chairman, catch basins of street drainage systems are often prolific sources of *Culex pipiens*. This nuisance may become sufficiently serious to discredit Anopheles control measures and to cause taxpayers to question the value of malaria eradication procedure. Because of the mosquito pest in such instances this subject may be considered a part of the malaria control campaign. We must provide something in the nature of a larvicide that will suit the local conditions. The fewer applications that must be made each season the better. The ideal to be sought is to provide a means of a single inexpensive treatment that will last for the entire season. The oiling of catch basins is not always successful and is too expensive. It has been tried out and is not economically effective. We must devise an economical method of eliminating the catch basin as a mosquito breeder. As a rule catch basins receive little systematic attention and often become filled with silt and mud and serve no purpose. One that is frequently filled might as well not exist. If the larvicide applied is not repulsive to culex or stegomyia, but will prevent the hatching of eggs laid in catch basins it will prove very satisfactory.

Mr. Hoskins. Mr. Chairman, we made some experiments with niter cake at Columbus. If you ask us what we are going to do with catch basins I would advise knocking out the bottom of them; they are designed to catch the coarser material that would otherwise go into the sewers. I agree with Mr. Le Prince that the best thing to do is to eliminate the catch basin.

Mr. Bishop. Mr. Chairman, I have had very good success with water gas tar. You can get it at any gas plant. We have made a number of experiments with it. It can be used straight and it contains some phenol and creosote that are absolutely poison to larvæ, and I think everyone will find that it is worth trying out. We used water gas tar to a considerable extent as a larvicide and substitute for crude oil. This was used because it could be obtained without cost and can be obtained at any plant that manufactures water gas at not to exceed 5 cents per gallon. However, the amount made at this station is only about 60 to 100 gallons per day, as only part of this plant makes water gas. Owing to the fact that crude oil is difficult to obtain at this time, and to the fact that the Army has been supplied with a low grade of fuel oil in lieu of crude oil, and that the only way this fuel oil can produce an effective film is by the addition of the proper proportion of kerosene, this sug-

gestion is made with the hope that it may prove as beneficial and effective at other stations where water gas tar is obtainable as it has here.

The following is an analysis giving the percentage by volume of the contents of water gas tar:

	Per cent.
Water	76.5
Benzene	.28
Toluol	.90
Light paraffins	2.00
Solvent naphtha	4.15
Phenol	trace
Middle oil (naphtha)	6.92
Creosote oil and green oil	5.70
Naphthalene	.30
Loss	.90
Coke	2.30

The large percentage of water, of course, can be practically eliminated when handling the tar if desirable.

The tar can be applied through the ordinary spray cans, with drip cans, or with waste and sawdust, and can be mixed with kerosene, also with kerosene and crude oil, or with kerosene and fuel oil. The mixture should be approximately in the following proportions, depending upon the temperature and the method of application used:

1. From one-half to 1 gallon to 5 gallons of kerosene.
2. One quart to 1 gallon tar to 2 gallons crude to 5 gallons kerosene.
3. One quart to 1 gallon tar to 2 gallons of fuel oil and 5 gallons kerosene.

An application of the above mixture has produced a lasting film on quiescent water that will not be blown readily to one side of pond. This is due principally to the fact that the tar itself has practically the same specific gravity as water and has a tendency to float slightly under the surface of the water. Owing to the chemical properties of the tar the larvæ are killed in less time than it requires with a film of oil.

In applying the oil and tar mixture to the surface of water by waste the following method is used with good results at this station. A ball of waste about 6 inches in diameter is saturated with a heavy mixture of tar and kerosene, and then anchored below the surface of the water. The difference in the specific gravity of the water and oil causes the oil to come to the surface. The regularity with which drops will rise to the surface can be governed by the content of kerosene and heavier oil; it may also be brought to the surface by capillarity by leaving a ribbon of waste floating on the water.

Another by-product from making gas can be obtained from any plant for the asking. This is used filtering material and has the following analysis.

	Per cent.		Per cent.
Sulphur	40	Cobs	30
Iron	5	Tar	10
Prussian Blue	trace	Other material and water	15

This material has been found to be effective as a deodorizer as well as a fly and mosquito larvicide for use around privy vaults, stock pens, and manure piles.

Dr. METZ. Mr. Chairman, if I may say just one word about the niter cake method: I think it may be very effective in some place, but it may lead to trouble if not carefully watched. We had a large swamp that took refuse from a chemical factory. The chemical waste was mostly niter cake, apparently, and it so happened that just enough of it got into the swamp to prevent the breeding of *A. punctipennis* and *A. quadrimaculatus*, but *A. crucians* bred in tremendous numbers. Regarding the creosote method, it is decidedly in the experimental stage right now, but it seems to me that it would be worth while for everyone to try it out. There are different grades of creosote, some more effective and some less effective. Try to find out the exact grades of creosote you use and record the kinds that are most effective.

Mr. HARRUB. Mr. Chairman, an article known under the trade name of Kreolis is put out by a chemical manufacturing house in Jacksonville. They were very anxious to have me try their product in malaria control work, and offered to furnish the material for demonstration. We tried it on a small pond, perhaps a half acre in area. It killed the larvæ all right, also all other aquatic life, including frogs and fish up to six inches in length.

The most serious objections to the use of this method of control of mosquito production on small ponds are: First, the cost of the material. In order to produce a lethal dose, the volume of the water to be treated must be taken into consideration, whereas with oil only the surface area need be considered. In other words, increase in depth means an increased amount of larvicide, but not of oil. Second, leaving the determination of the amount of the larvicide to be applied to the judgment of the ordinary oiler is unsatisfactory. If an insufficient amount is applied the desired results will not be obtained, and if an overdose is applied our best natural aid, the fish, will be killed. There is then no natural control. Third, the effect is not lasting as claimed by the manufacturers, because the vegetable matter in the bottom of the pond soon neutralizes the toxic effect of the larvicide.

In the case of the pond mentioned above, breeding was much worse soon after the experiment than it had been before, and regular oiling was necessary thereafter until we finally eliminated the pond by

getting the railroad company to put in a culvert under their right of way.

Mr. Hoskins. Mr. Chairman, we made experiments with niter cake at Columbus which were not encouraging. The active agent of niter cake is free sulphuric acid and we found that the natural alkalinity of the soil neutralizes such an amount of the acid that its use in lakes and natural pools is impractical. In artificial containers such as barrels this objection does not obtain.

Regarding the question of larvicides in catch basins it seems advisable whenever possible to eliminate the catch basin by knocking out the bottom. We propose following this procedure in Columbus.

Dr. Carter. Mr. Allen has prepared a paper for us on the determination of the relative sanitary importance of the prevalence of malaria. We will now hear from Mr. Allen.

THE DETERMINATION OF THE RELATIVE SANITARY IMPORTANCE OF THE PREVALENCE OF MALARIA, THE COLLECTION AND EXAMINATION OF STATISTICAL DATA RELATIVE TO MORBIDITY AND MORTALITY OF MALARIA, AND THE APPROXIMATE PERCENTAGE OF THE COMMUNITY AFFECTED BY MALARIA.

A. F. Allen, Scientific Assistant.

It is always necessary to know definitely the results accomplished in antimalarial activities. It is necessary to know these for two reasons—(1) to justify the expenditure of moneys that may have been made, as was the case in the past year when, under an emergency, moneys were spent without a previous estimate being made of the results that might be attained, and (2) in order that from the results accomplished arguments can be prepared to establish the need of either continuing the work that has been started, or of inaugurating work in new regions.

The results accomplished in antimalarial activities may be discussed briefly under three headings, namely, the physical work done, the reported reduction of mosquito prevalence, and the reported reduction of malaria.

The physical results accomplished include the number of miles of ditches dug, the streams cleared, ponds under control, the number of gallons of oil sprayed, the amount of larvicides of various kinds used, the number of houses screened, and the amount of quinine distributed, together with such other data as develop in the work.

From the reports of various inspectors employed, one can determine approximately the results of the reduction of adult mosquitoes, if any such be found, their type, and also the extent to which mosquito development in the aquatic stages has progressed. Usually it is impossible to determine the reduction of adult mosquitoes save by occasional remarks of residents in the area under control.

The third of the various results accomplished in antimalarial activities is the subject of this paper, namely, a study of the sanitary importance of the prevalence of malaria as a disease among the populace of the region in which control measures may have been in effect. It is not the purpose of this paper to discuss the fundamental details of statistical methods of study. Reference can be made to Supplement to Public Health Reports No. 12, "Vital Statistics," by Surg.

John W. Trask, in which will be found a complete discussion of the various fundamental principles of collection, tabulation, and examination of figures relative to vital statistics.

In all malarial work there are certain sources from which statistical data may be obtained. We have (1) the official reports of morbidity and mortality on file with the proper governmental authorities, (2) the records of hospitals and institutions, (3) the records of insurance companies showing sickness insurance as well as death insurance, (4) the records of local nursing associations together with estimated statements from the nurses themselves as to the approximate number of malarial cases and deaths which come under their indirect observance, (5) the unreported observations of the practicing physician, and (6) an accurate house-to-house canvass either of the region as a whole or of a selected typical section of this region.

Malaria as a disease varies from the acute type down through various gradations and modifications to the extremely mild oftentimes unrecognizable type which may be associated with such other symtoms as to obscure the exact nature of the disease. This fact adds to the difficulty in securing accurate statistical data on malaria. It may be stated that during a study of mortality records one oftentimes enters as a death due to malaria, a death record in which the primary cause of death is stated to be from causes which may be directly attributable to malarial infection and in which case malaria is stated to be the contributory cause of death. It is usually impossible in reports of cases of malaria to go further than as stated on the face of the report, save in cases where it may be possible to make an epidemiological investigation.

It is oftentimes necessary, when making a house-to-house canvass for the purpose of rapidly determining the normal amount of malaria, to establish some arbitrary definition of malaria. The writer has found it advantageous to do so in some instances, and has found that a definition involving a history of distinct chills and fever, sufficient to cause the patient to go to bed, will establish the facts of a case and largely remove the question of complication with other diseases.

Having collected and tabulated the data from all available sources, it is necessary to study these in order to determine the possibility of further reducing them, or for the purpose of determining the results actually accomplished.

The State of Mississippi probably has the best data at present on the subject of malaria. For the last 5 or 6 years particular emphasis has been laid on securing complete reports of this disease. The population of the State of Mississippi is given as 1,551,270 in 1900, and 1,797,114 in 1910. Assuming an arithmetical increase in pop-

ulation, we have a population in 1916 of 1,944,618. In view of the fact that most of the data to be mentioned later are estimated, and are usually accurate only to two significant figures, we can safely assume that the population of Mississippi to be used for discussion in this paper is 2,000,000. There were reported in 1916, 158,751 cases of malaria, with 1,426 deaths, or a rate of 0.900 per 100 cases, or approximately 1 per cent. It is evident from this that even with this enormous number of reported cases in the State, that all of the cases are probably not reported, since it is the experience of the men best qualified to judge of such matters, that the mortality rate probably runs from one-fourth to one-third of 1 per cent.

If on a basis of these reported deaths we estimate the number of cases that would have occurred if deaths had been one-third of 1 per cent, we find that we have 427,800 cases. Therefore, in the State of Mississippi, with a population of 2,000,000, we have somewhat more than 400,000 cases, or approximately one person in each five, suffering an attack of malaria infection each year.

In estimating the results of the work done in the reduction of malaria within any area, it is necessary that some check area in which no control measures are carried out be obtained for the purpose of comparison. Usually it is impossible to secure two areas of approximately the same size in which mosquito-breeding conditions are so identical as to make comparison between the two regions possible. It is necessary therefore to look for some other source of data for comparative purposes, and it is usual to take the larger legal unit in which the area in question is situated, namely, either the county or State, for this comparison.

In the work in Mississippi we have made comparisons with the State as a whole rather than with the county in which the controlled areas were located because of the fact that at least in one county the records were rather insufficient and probably somewhat inaccurate, and because of the fact that the relative accuracy of the State figures was somewhat greater than the county figures. As noted above, only in the last 5 or 6 years has particular emphasis been laid to reporting malaria in the State as a whole. The following table gives the total number of reported cases and deaths of malaria by years from 1914 to 1918, inclusive:

Year.	Reported cases.	Reported deaths.
1914	116,788	1,030
1915	153,707	1,492
1916	158,751	1,426
1917	140,687	999
1918	105,783	[1]

[1] Not available.

It is noticed that from 1914 to 1916 the number of cases increased and subsequent to 1916 decreased. Possibly the increase in the first two years was due to a greater diligence on the part of the physicians in reporting this disease, although data in other localities show that 1916 was a rather malarious year. There may be several reasons for the drop in the last two years, but no doubt it is in part due to the fact that 1917 and 1918 were both known as dry years, although there is some question as to the effect of a dry year on the amount of malaria resulting. Another possible reason for the drop in the past two years is the fact that many physicians from the State went into the Army, with the resulting impossibility of many people to secure the services of a physician for minor illnesses. Also on account of the unusual amount of work thrown on the remaining physicians, they often failed to report malaria cases. The epidemic of influenza increased this falling off in the last year since the physicians were too busy to attend to or report malaria, and many times malaria was mistaken for influenza and was reported as such. Mention should be made of the fact presented by Mr. Frederick L. Hoffman, entitled, "Plea and plan for the eradication of malaria throughout the Western Hemisphere," published by the Prudential Life Insurance Co. This fact is that during the past 15 years there has been a very marked reduction in reported mortality of malaria. Mr. Hoffman's figures show that the mortality rate of 20 southern cities has dropped from slightly more than 50 per 100,000 population in 1900 to just a little more than 10 per 100,000 population in 1914, or an approximate reduction of 80 per cent during a period of 14 years. If this rather general reduction in malaria prevails, it must influence our estimates of results accomplished by direct antimalarial control measures. We are unable, however, to properly determine the facts and can at best only accept the reported figures and discount if possible the apparent reduction accomplished.

It may be interesting to make brief reference to the work in Jackson, Miss. In the city of Jackson 1,582 cases were reported in 1917, as compared with 564 cases in 1918, a reduction of 64 per cent. The reduction in the State as a whole between these two years may be estimated from the above table to be 24 per cent. Control measures were in effect in 1918 in the city of Jackson. Had they not been in effect we might have expected 75.2 per cent as many cases in 1918 as occurred in 1917, if the same ratio held in the city as in the State. Instead, only 35.6 per cent appeared; therefore the actual reduction accomplished was only 52.6 per cent instead of the apparent reduction of 64.4 per cent. This method of discounting apparent results must be used if we are to obtain an honest estimate of the actual results accomplished.

Due to the fact that probably most of the cases reported during the spring of the year are recrudescences of infections from previous years we can oftentimes obtain a more accurate index of the actual results accomplished in the reductions of new infections of malaria by studying reported figures of malaria occuring during the months in which new infections may take place. This period will vary according to the various geographical and climatogical locations, but the months of July to September, inclusive, may be safely taken for this purpose. During these months in 1918 only one-half as much malaria was reported in the State of Mississippi as was reported in the corresponding months in 1917. If, therefore, this method of determining the results of the work is used, the apparent percentage reduction of malaria must be discounted 50 per cent.

When estimates have been made of the number of malaria cases and deaths that may have been prevented, or, in such cases as estimates are prepared, of the possibility of preventing such cases and deaths, it is oftentimes advisable to assign an approximately monetary value for each case of malaria and death, in order that a sum of money may be determined upon as a cash value of the work done, or that it is possible to do, in the saving of human lives or sickness. Oftentimes this is the most advantageous method of presenting the need of continuing work or of inaugurating such work to civic and government bodies. This method of arriving at a cash value of the work done can at best only be approximated, but if it is possible to secure the figures of payments made by insurance companies for malaria in the same region before and after control measures are inaugurated, it is often possible to secure some startling results. For instance, it may be stated that in the city of Jackson, Miss., the amount saved to the insurance companies alone in payment made on malaria was more than twice the amount expended in malaria control measures.

General Discussion.

MAPPING.

Mr. Le Prince. Mr. Chairman, I want to make a few remarks concerning mapping or drainage schemes. I have noticed that one or two engineers have been wise enough to use a title for their maps, similar to the following one: "California State Board of Health Antimalaria Campaign—Map Showing Drainage Scheme, etc." We have in this case given the credit to the State health administration of California whom the people have not looked up to as much as they should. Our work is to help the State health officers to inaugurate this antimalarial work. The object of our work is ultimately to rid the United States of malaria. And in carrying on our work there

is no need of advertising the United States Public Health Service. We are not out to advertise ourselves. We must use every means to strengthen the local, county, and States health organization, and never miss an opportunity to get the public to take an interest in the work of the State department of health.

GARBAGE DUMPS.

Dr. Griffitts. Mr. Chairman, I want to invite attention to the fact that a city may frequently be induced to make valuable use of its garbage. It can be used to fill up Anopheles breeding places and thus effect a great saving.

At Newport News we had some bad Anopheles breeding places almost in the camps and absolutely got rid of them by having the garbage diverted to them. All kinds of garbage may be thrown in these places in the winter time without objection. If the filling is not completed by the approach of warm weather, at least, the water will have been rendered too foul for Anopheles breeding.

Mr. Le Prince. Mr. Chairman, I think that every town that allows garbage to be dumped should be required by ordinance to dump garbage in the manner indicated by the local health officer. We should make the garbage dumps very low, so as to cover up a larger area than is now covered by the dumps.

DATE OF CONCLUDING MAINTENANCE OPERATIONS.

H. R. Carter, Assistant Surgeon General.

Gentlemen, Mr. Le Prince has asked me to say a few words to you regarding the habits of the mosquitoes and the date of concluding maintenance operations. We do not care how late the mosquitoes breed if those mosquitoes are not capable of conveying malaria. An Anopheles, when the temperature is below 60° F., is just as innocent as a Culex. So we have begun to make determinations as to the latest infectivity of the Anopheles, fixing the date in the different localities. After that time the Anopheles is innocent of conveying malaria. We made our observations first in Louisiana—at Monroe. In 1917 Mr. Mitzmain conducted investigations there. The last date at which infection was found in an Anopheles was October 20. Now let us see when that Anopheles was developed. From the time the mosquito bites to the time the infection develops, in ordinary summer time, is about 11 days. From the time the egg is deposited to the time it develops as a winged insect is about 16 days in summer time. In other words, in summer weather the eggs must be deposited 28 days before she is capable of infecting a man. As the weather grows colder this time lengthens. It lengthens by more than 50 per cent. So to the 28 days add 14, making 42 days. Now 42 days previous to the 20th of October is the 8th of September. If all eggs and larvæ were destroyed on the 8th of September there would be no infection from eggs laid later than that date at that place in that year. In this locality, oiling on the 8th of September would have rendered it impossible for malaria to be contracted in that section. Oiling again on the 9th would have been useless. Mosquitoes from eggs deposited after the 8th could not have conveyed malaria. We did not quite do that, however. We allowed 21 days as a factor of safety. This year, instead of continuing oiling, we ordered it stopped when we knew that no mosquitoes conveying infection would appear from eggs laid later. I think we saved possibly $25,000 by that. This is where biological observations come in practically with engineering problems. Knowledge of these facts helps the engineer and saves money.

Discussion.

Mr. Bishop. Mr. Chairman, is there any danger, if oiling is stopped the middle of October or first of November, of mosquitoes coming from another territory and hatching out a new brood which is liable to hibernate during the winter?

Dr. Carter. Every chance in the world, but they are no more dangerous than Culex. The date of stopping breeding is not where the danger lies. It is the date of beginning in the spring that is of sanitary importance. No amount of oiling in winter time has any effect on the breeding place in the summer.

I am going to close this conference. We have consumed two and a half days in the consideration of the different subjects. We could have put in that length of time on each subject with advantage. The man who carries nothing away from this conference will be either the man who brought a great deal with him or the man with very little carrying capacity. Admitting that many of us fall in the first category—I think all of us have room enough to get new ideas and new information which we will take away with us. When you go back to your work, as Dr. Metz said in his opening talk, remember that a great deal can be learned by a number of intelligent, trained men keeping their eyes open. When you make a new discovery, note it, and while it will only be a single fact, others will be sending in the result of their observations and soon we will have a half a dozen facts, which I need not tell you are thirty-six times more valuable than one.

Gentlemen, I am much obliged to you for your attention. The conference is adjourned.

The conference gave Dr. Carter a rising vote of thanks.

RELATED PUBLICATIONS.

AVAILABLE REPRINTS OR BULLETINS ON MALARIA ISSUED BY THE PUBLIC HEALTH SERVICE, FROM WHICH COPIES MAY BE OBTAINED WITHOUT COST.

PUBLIC HEALTH BULLETINS.

79. Impounded Water. Surveys in Alabama and South Carolina during 1915 to determine its effect on prevalence of malaria. By H. R. Carter, J. A. A. Le Prince, and T. H. D. Griffitts. 1916.
84. Is Mosquito or Man the Winter Carrier of Malaria Organisms? By M. Bruin Mitzmain. December, 1916.
88. Malaria Control: A Report of Demonstration Studies Conducted in Urban and Rural Sections. By R. C. Derivaux, H. A. Taylor, and T. D. Haas.

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28. Prevention and Destruction of Mosquitoes. By Joseph Goldberger. July 17, 1908.
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258. Malaria Control. Drainage as an Antimalarial Measure. By J. A. A. Le Prince. February 19, 1915.
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